Logistics Challenges 2001

Forecasting Readiness
MICAP Shipping Policies
BOS Competitive Sourcing and Privatization

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Forecasting Readiness

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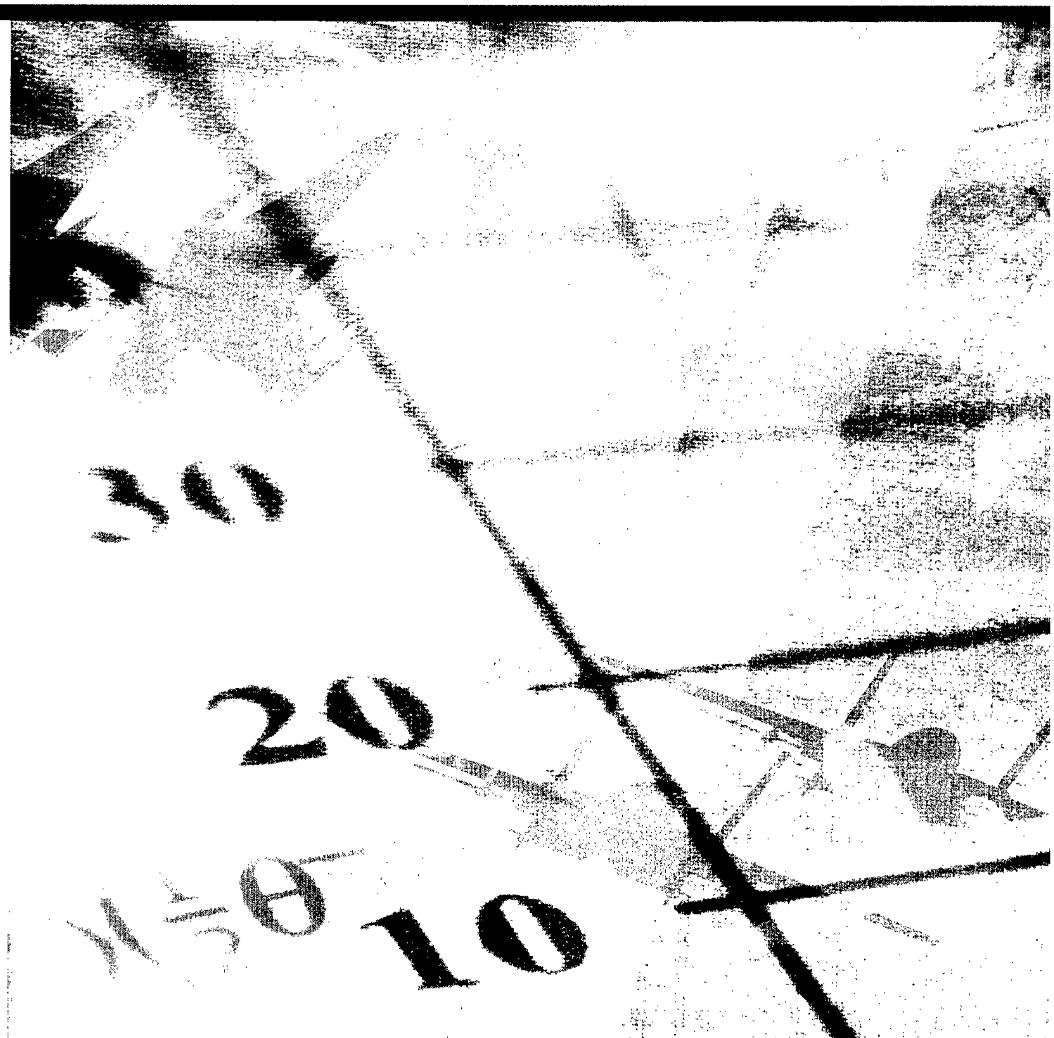


Regression Analysis Techniques

According to many experts, the readiness of America's Armed Forces deteriorated throughout the 1990s. The Chairman of the House National Security Committee, Floyd D. Spence, stated that the readiness of the Armed Forces has been jeopardized and there is "a real danger the Defense Department will return to the hollow forces of the 1970s."[1] During this time, combat readiness of the Air Force fighter aircraft has declined in varying degrees. One indicator of aircraft combat readiness, the mission capable (MC) rate, is used to identify the percentage of aircraft able to perform their primary wartime missions. The not mission capable (NMC) rate shows the converse. From fiscal year (FY) 1991 through fall 2001, the aggregate Air Force aircraft total not mission capable rate for maintenance (TNMCM) for all aircraft steadily increased from 7.6 percent to 18.1 percent while total not mission capable rate for supply (TNMCS) increased from 5.5 percent in FY86 to 13.4 percent in FY01 (Figure 1).[2] The erosion of MC rates appears to have stabilized, but concern still exists, and efforts to determine the reasons behind the decline continue. To illustrate the level of concern, in a 5 January 2000 memorandum to the Air Force Deputy Chief of Staff, Installations and Logistics, the Air Force Chief of Staff, General Michael Ryan, asked, "What are the main causes for increasing TNMCM rates over the last few years?"[3]

Currently, the Air Force uses the Funding/Availability Multimethod Allocator for Spares (FAMMAS) model to forecast overall MC rates for each mission design series (MDS) aircraft in its inventory. FAMMAS uses time-series forecasting techniques to predict overall MC rates for each MDS, using past, present, and future spares funding levels, along with the last 3 years of historical TNMCS and TNMCM data.[4] Numerous operational and funding decisions are made each year based, in part, on the predictions of this model.

Problem

While the FAMMAS model does an excellent job of predicting MC rates for each MDS based on funding data and planning factors, it does not adequately

(Continued on page 29)

Captain Jason L. Masciulli, USAF
William A. Cunningham III, PhD

The Air Force and Department of Defense (DoD) spend significant amounts of money each year shipping mission-capable (MICAP) items throughout the world. This article and the research supporting it show that current Air Force shipping policies are less than optimal from a cost standpoint. The article also examines the idea of reducing these costs through another mode of transportation: express less-than-truckload (LTL). A comparison of Roadway and Federal Express (FedEx) shipping costs showed that cost savings could be realized by using Roadway in conjunction with FedEx.

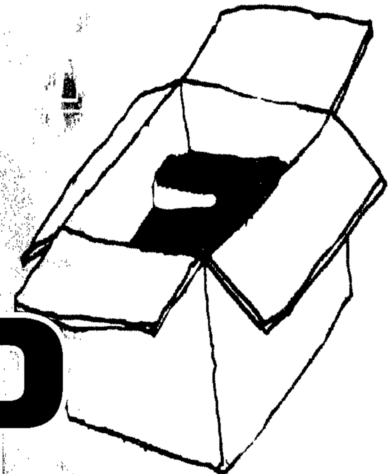
Policy Review

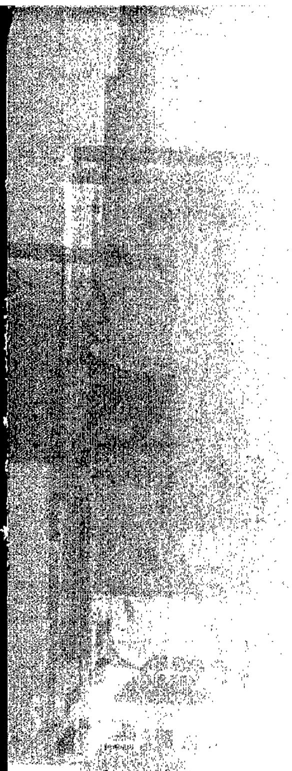
Three Air Force and DoD regulations or instructions govern shipment of MICAP items. While Air Force Instruction (AFI) 24-201, *Cargo Movement*, regulates cargo movement, it does not require a specific mode for shipping MICAP items within the continental United States (CONUS), although it does require movement by the fastest traceable means aboard the General Services Administration contract carrier.[1] The instruction establishes shipment time standards and states, "Commercial air express small-package delivery service . . . is the norm for Agile Logistics/2LM [two-level maintenance]/Rapid Parts Movement shipments to meet Air Force sustainment goals."[2] Defense Transportation Regulation (DTR), Part 2, *Cargo Movement* (the basis for AFI 24-201), establishes shipment time standards and allows use of expedited service when the shipment is urgently needed.[3] *Air Mobility Command (AMC) Freight Traffic Rules*, Publication No 5, states, "Commercial air service will not be used for transportation of shipments to be delivered within 500 surface miles from the shipping point except when commercial air is the low-cost mode or is the only mode that can meet shipment requirements."[4] However, the definitive word comes from AFI 24-201:

> 6.1. General Services Administration (GSA) Small Package Contract Carrier. High-priority shipments, that meet the contract terms, will move via GSA contract carrier to DoD and contract addresses to/from CONUS, Alaska, Hawaii, and Puerto Rico. Therefore, high-priority shipments, 999, NMCS [not mission capable—supply], MICAPs, Agile Logistics/2LM/Rapid Parts Movement, destined to/from CONUS Alaska, Hawaii, and Puerto Rico should be moving by the GSA contract carrier from pickup to delivery at the consigned destination. The DoD is a mandatory user of this contract, *except* in the following instances:
>
> 6.1.1. DoD shipments between 0 and 500 miles from origin.
>
> 6.1.2. DoD shipments under DoD contracts or guaranteed traffic agreements in effect prior to award of this contract until expiration of the existing contracts or agreements.
>
> 6.1.3. When required by wartime contingency operations.
>
> 6.1.4. When shipments are outside the scope of the contract. (Presently, International Merchant Purchase Authorization Card [IMPAC, now referred to as the Government Purchase Card] micropurchase accounts cannot charge transportation costs under the GSA small package contract service to obtain the special government rates).
>
> 6.1.5. Individual shipments with a gross weight of 151 pounds or more are outside the scope of this contract.[5]

Air Force MICAP Shipping Policies

Are they optimal from a cost standpoint?





Currently, FedEx has the GSA small package contract. As a result, the analysis uses their rates for comparison with Roadway ground rates.[6]

Methodology

Two sets of data were used to compare the cost differences between air and ground movement of MICAP items. The simulated dataset consisted of items that could be shipped by either air or ground mode. This data had only two pieces of information: the weight, ranging from 1 to 150 pounds, and a distance range, from 0-50 miles to 3,401-3,500 miles from origin to destination. To compare every possible type of shipment, each datum represented 1 of the 11,100 possible shipments for which both an air and ground rate can be acquired.

The second set of data was actual MICAP shipping information for parts traditionally shipped *expedited air*. Most of these shipments were to and from AMC bases in July 2000, but a few were to or from other locations. The Air Force Materiel Command (AFMC) Logistics Support Office, Cargo Movement Division provided the initial actual data set—5,636 MICAP shipments moved by air carriers, predominately FedEx.

Rate tables were acquired for FedEx and for Roadway Express, which has the government's express LTL shipping contract. The FedEx rates were for CONUS shipments and to and from Hawaii, Alaska, and Puerto Rico, regardless of the distance from the origin, from 1 to 150 pounds in weight, in 1-pound increments. Roadway's rates, however, were based on hundredweight and distance, resulting in simulated shipments ranging from 1 to 150 pounds in weight, in 1-pound increments, and 74 different distance intervals. Adjustments were made to allow comparison of FedEx and Roadway rates. The air rates were from the March 1999 FedEx *US Government Service Guide*.

Simulated data were used to (1) show the cost differences between air and ground, (2) show possible shipments using air or ground, and (3) calculate the rate difference between each air and ground rate moved by air carriers.

The data provided by AFMC was used to determine if there would be any cost savings using ground transportation instead of air for actual shipments.

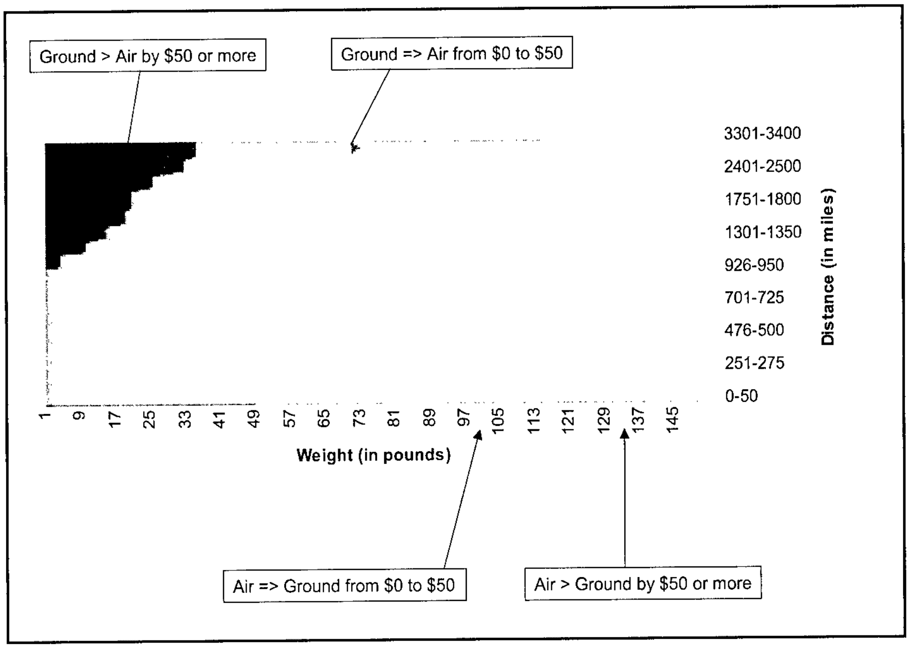


Figure 1. Carrier Rate Differences Based on Weight and Distance

Simulated Data Analysis and Results

There were 5,522 instances where the rate difference was negative, which means that ground transport was more expensive than air. Conversely, there were 5,572 rate occurrences where the difference was positive—the air rate was greater than the ground rate. There were six rate differences where the rate difference was zero, meaning the air and ground rates were equal.

Figure 1 provides a breakdown of the rate differences for the shipments and indicates that ground transport becomes more costly than air movement as the distance increases and the weight decreases. It also shows that air transport becomes greater in cost as the weight increases with a smaller distance range. The border between the dark gray and gray regions is the breakpoint where there is minimal difference in using either air or ground transportation. If the distance is short and the shipment heavy, the ground mode is favored, while air shipping should be used if the shipment is light and traveling a longer distance. Overall, heavier shipments should go ground regardless of distance from the origin, while lighter shipments should go air. Where the shipment's weight and distance to be traveled are known, the rate difference table can help make a decision on whether it is less costly to ship the item by ground or air transportation.

The data also show that, out of the 11,100 simulated shipments, 5,572 (50.19 percent) would be less expensive shipped Roadway than FedEx. Further, the results show cost savings would be realized if those shipments within the weight-and-distance range criteria where Roadway is the lower cost shipper were sent via Roadway.

Actual Data Analysis and Results

There are two trends in the actual shipment data for July 2000. Figure 2 is a histogram of the shipment weights from 1 to 150 pounds in bins of 10. It shows a highly skewed distribution toward low-weight shipments. Out of the 3,451 shipments, 2,479 (71.86 percent) weighed 10 pounds or less. There were 1,084 shipments (31.41 percent) that weighed 1 pound.

Table 1 provides statistical data for shipment weights. The statistical data show the weight distribution is a highly skewed right distribution. They also show that the shipments, based on their weights, are more conducive to moving via FedEx than Roadway.

Mean	12.1
Mode	1.0
Median	4.0

Table 1. Statistical Data on Shipment Weights

Figure 3 provides a histogram of the distance ranges for shipments. The distance range data for shipments show little, if any, trend. However, it does indicate that shipments are grouped in several areas—predominately toward the longer distance ranges, with a peak at 2,701-2,800 miles and a slightly shorter peak at 2,801-2,900

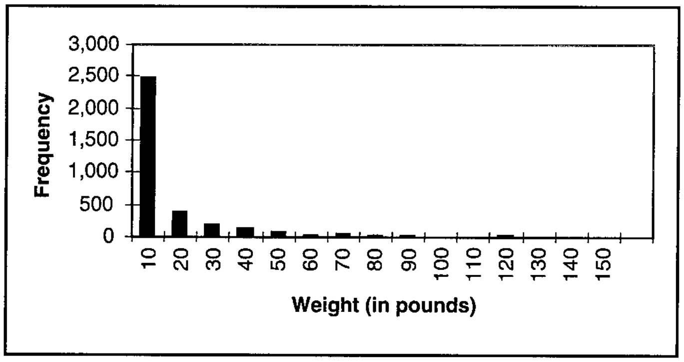


Figure 2. Histogram of Weights in Actual Shipment Data

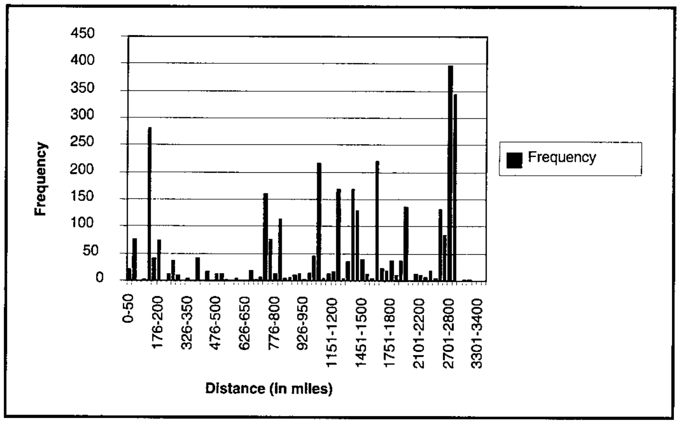


Figure 3. Histogram of Distance Ranges for Shipments

miles. There is also a shorter peak at the lower end of the distance ranges at 126-150 miles. Of the 3,451 shipments, 633 (18.34 percent) traveled 500 miles or less. Technically, these shipments should not have been moved via FedEx. On the other hand, 2,818 (81.66 percent) were shipped more than 500 miles. In these cases, the shipments' distance ranges were appropriate for the use of an air carrier. However, there are shipments in the data, from a cost standpoint, where it would have been better to move them via a ground carrier.

Using only FedEx rates, the total cost of shipments was $35,056.53. Conversely, using only Roadway's rates, the total cost was $132,644.00. DoD would have spent $97,587.47 more for these MICAP shipments if only ground transport had been used. However, if DoD had used the carrier with the lowest rate, whether FedEx or Roadway, for all shipments, the total cost would have been $31,228.26. This means DoD would have saved $3,828.27—a savings of 10.92 percent. If an 11-percent savings were realized for all MICAP shipments by using ground transport where the cost was less expensive compared to air, then the Air Force and DoD could achieve significant savings. These calculations are based on available information, and it is possible that the future actual costs would be different if shipping rates changed drastically. However, based on the available information, the analysis shows a cost savings would be realized if the LTL carrier, Roadway, were used when its rate for the shipment was less than FedEx for certain shipments. Unfortunately, there is a problem in using Roadway as opposed to FedEx. The transit time would not meet the standards as set by Air Force regulations. The specified time for transportation priority 1 or 2 shipments, which MICAP items fall under, from pickup to delivery within the CONUS, is 1 day.[7] FedEx can provide that via priority overnight service under the GSA Small Package Contract.[8] According to DoD standards, the actual transit time varies depending on the origin and destination. The standard DoD transit times for LTL are listed in DoD 4500.9 DTR Part II, *Cargo Movements*, Chapter 202N.[9] This reference states that the standard transit time for transportation priority 1 shipments via LTL, between pickup and delivery, is based on the state of origin and the destination. For example, a shipment originating at Dover AFB, Delaware, moved via LTL to Charleston AFB, South Carolina, has a transit time standard of 3 days,[10] which does not meet the standard in AFI 24-201. In fact, none of the LTL standards on this table (Figure 202-3 in DoD 4500.9, DTR Part II, Chapter 202) meets the AFI 24-201 standard. The shortest transit time standard on the table is 2 days. An LTL carrier may be able to provide a transit time meeting that standard. If it can and meets the true time delivery need and the rate is lower than FedEx, the LTL carrier should be used.

Recommended Research

While the research for this article focused only on MICAP shipments, it could be applied to all types of Air Force and DoD shipments to evaluate whether other modes of transportation are viable alternatives for shipments within and outside the CONUS.

Another analysis could look at modal choice alternatives for MICAP items in other theaters. For example, a study could look at MICAP shipments in Europe using LTL as opposed to the World Wide Express contract for the leg of the shipment that could be moved via LTL. Also, the data used in these studies could be expanded to include all types of shipments.

With regard to transit time standards, a serious analysis needs to be made of overnight shipment requirements. Otherwise, the Air Force may not avail itself of cost savings. The fact that Air Force transit time standards for transportation priority 1 and 2 shipments are 1 day questions the need for three transportation priorities if the transit time standard is the same for the first two.

Several questions need to be asked to help determine if the part requires overnight delivery. For example, is the part being shipped overnight truly needed immediately? Can the customer's needs be met by using another mode?

The Air Force and DoD need to determine if they are using the right carrier for MICAP shipments. Can MICAP items be shipped at a cheaper rate using UPS, Airborne Express, Emery, DHL, or some other overnight air carrier? Does the GSA contract restrict DoD's ability to get the best value for its money for shipping MICAP items?

Also, is the use of FedEx so ingrained in the Air Force and DoD corporate culture it is automatically assumed and used as the carrier for MICAP items and other time-critical shipments without regard to cost, distance, or other factors? In the actual shipment data, there was a 69-pound shipment from Tacoma, Washington, to McChord AFB, Washington, via FedEx. The distance between these two points, according to the Defense Table of Official Distances, was 11.4 miles. There were also 20 shipments, ranging in weight from 1 to 26 pounds, via FedEx from Port Orchard, Washington, to McChord AFB. The distance between these two points is 37.9 miles. There was a 2-pound shipment from Yuba City, California, to Travis AFB, California, a distance of 72.5 miles, via FedEx.

(Continued on page 40)

How Are We Doing?

Base Operations Support Competitive Sourcing and Privatization

Major Kurt A. Kitti, USAF

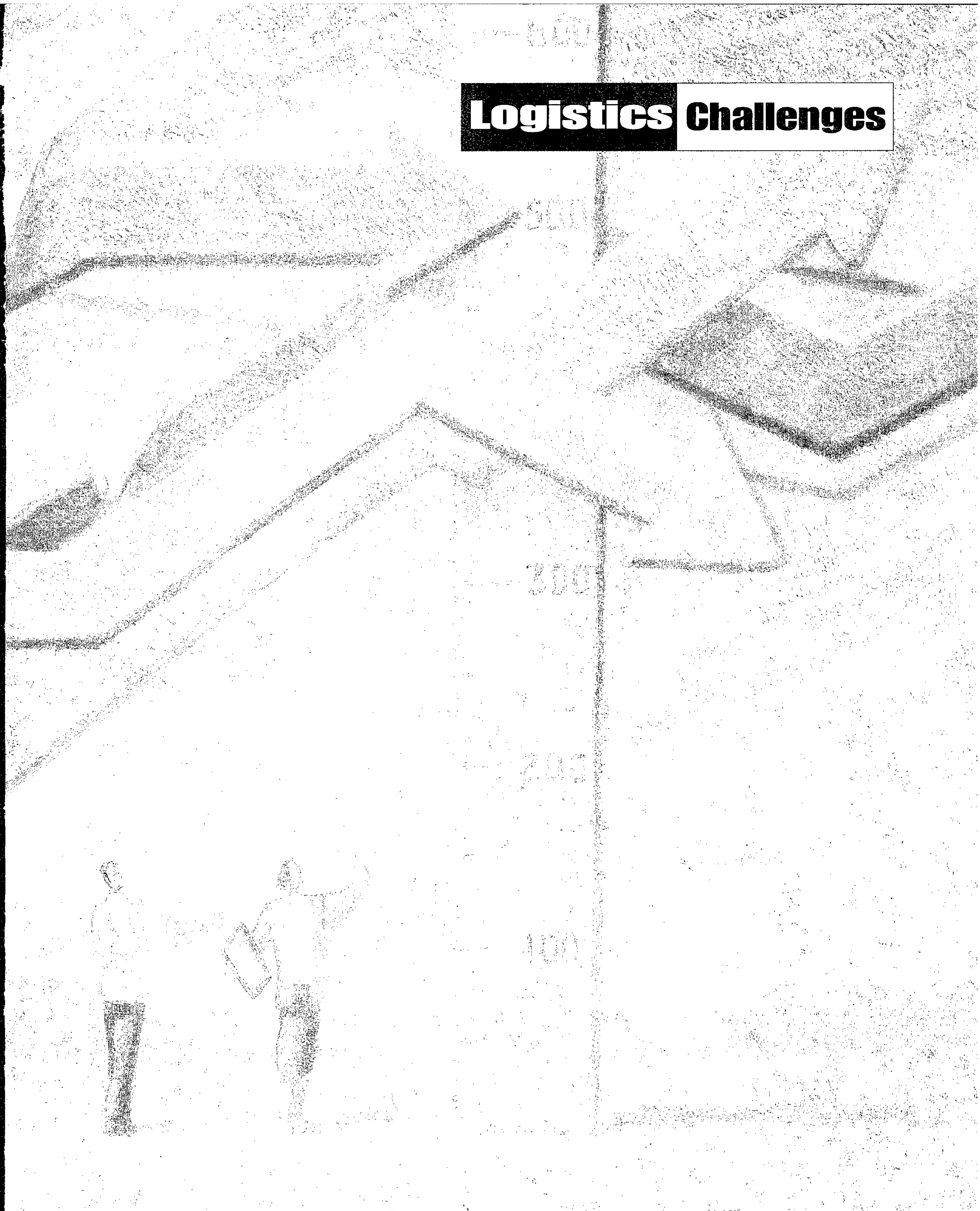
The Air Force is pursuing competitive sourcing and privatization to free up dollars for its highest priorities, especially modernization.

The Air Force is committed to pursuing outsourcing and privatization initiatives across our service . . . we are stepping back and taking a broad look across our service to identify opportunities to produce a better Air Force, based on excellence in processes and performance in both combat and support areas that will provide the air and space capabilities required for the future.

—General Ronald Fogleman

Since 1955, the Department of Defense (DoD) has been encouraged to obtain commercially available goods and services from the private sector through competitions when such action was cost-effective. However, over the years, numerous changes in law inhibited DoD outsourcing efforts. Then, in 1996, shrinking defense budgets, force downsizing, and lack of procurement money for modernization led to a relaxing of some legislative restrictions, thus sparking renewed interest in outsourcing. Today, at the forefront of DoD's outsourcing revolution, the Air Force is aggressively pursuing competitive sourcing and privatization (CS&P) to free up dollars for its highest priorities, especially modernization. As defense budgets have continued their decline, the Air Force has turned to outsourced base operations support (BOS) services as a key opportunity for cost savings and improved efficiencies. Enormously diverse—both in size and complexity—the practice of consolidating or *bundling* separate base services into one large BOS contract has been steadily growing across

Logistics Challenges



the Air Force. These BOS initiatives range from continental United States (CONUS) main operating bases to forward operating bases, air stations, and remote radar sites in the United States and foreign countries. Accordingly, many different government BOS program and contract management organizational structures have been created to oversee or manage contractor performance—some more successfully than others.

Many early BOS challenges grew out of the initial rush to outsource and lack of a comprehensive, Air Force-level strategic direction or policy to organize, educate, train, and facilitate the radical paradigm shift to commercially provided BOS services. The result has been fewer cost savings and less effective BOS management. But significant cost savings and improved BOS support to the warfighter can be achieved through careful organizational restructuring, strong investment in personnel education and training, and continuing BOS process improvements.

Competitive sourcing is designed to maximize cost-effectiveness and efficiency, thus enhancing mission capability, by using services available in the commercial sector, with the government retaining ownership and control of the activity. On the other hand, *privatization* is the actual transfer of control and ownership of a target business asset and associated activity from the public sector to the private sector. Here, the government gives up responsibility and control of the activity. Another essential feature of privatization is the shift to the private sector of long-term financial investment to sustain the activity.[1] Although most BOS services fall under competitive sourcing, other areas such as base housing and utilities and those installations affected by base realignment and closures are becoming privatized, with a host of possibilities for strategic alliances with a number of players. This article addresses only those BOS activities related to competitive sourcing.

Beginning in 1997, the Air Force established four principal CS&P goals: sustain readiness, improve performance and quality by doing business more efficiently and cost-effectively, generate funds for force modernization, and focus personnel and resources on core Air Force missions.[2] To achieve these ambitious goals, the expanded outsourcing of BOS services was viewed as a key area for potential improvements and future cost savings. Since every Air Force installation has an extensive and well-developed service support infrastructure, the possibilities for outsourcing various combinations of support services are substantial. However, because the initial wave of CS&P was implemented so quickly (before clear, Air Force-level policy and detailed guidance were available), major commands (MAJCOM) and bases developed their own, often ad hoc, approaches to select activities for outsourcing. Even more problematic was the requirement to follow a cumbersome, bureaucratic, and slow A-76 process while trying to develop (often from scratch) good performance work statements (PWS), quality assurance surveillance plans (QASP), and contracts. This often resulted in an ambiguously worded, military specification/military standard (MILSPEC/MILSTD), *how to* work statement developed separately from a compliance-oriented military inspection checklist QASP, both of which were disconnected from the legally binding service contract instrument.

Fortunately, recent acquisition reforms and steady improvements in Federal, DoD, and Air Force statutory guidance and policy direction have led to overall improvements in CS&P and BOS management. Today, Performance-Based Service Acquisition (PBSA) and Business Requirements Advisory Group (BRAG) initiatives offer the promise to achieve all four CS&P goals—and most importantly—to optimize support to the warfighter. Perhaps even more promising are the many leading-edge practices and innovations coming from a growing number of Air Force BOS management organizations. Successful BOS implementation by these organizations is putting the theory into practice and helping pave the way for future BOS improvements.

Base Operations Support Problem Areas

Analyzing your present culture is like going to history class, when you could learn more valuable stuff from studying the future . . . . Cultural change should be guided by where the organization needs to go, not by where it's been.

—Price Pritchett
High-Velocity Culture Change

Problems in Defining and Measuring BOS

BOS services are generally those functions necessary to support, operate, and maintain DoD installations. Although the Office of Management and Budget identified 29 different services as base support functions, neither DoD nor the military has a generally accepted definition for them. Without the framework of a common definition, it is difficult to measure the size and cost of the base support work force. Yet, there is a clear need to do so since DoD estimates that BOS activities cost more than $30B in fiscal year (FY) 1997.[3]

Numerous studies—including the 1993 Bottom-Up Review, Quadrennial Defense Review, Defense Reform Initiative, and National Defense Panel—have concluded that DoD could achieve the largest savings by using a single *omnibus* (that is, bundled, umbrella, or BOS) contract, instead of several smaller contracts, to encompass multiple BOS services.[4] This conclusion has fueled the growing interest in BOS across DoD. In particular, the Air Force is projecting a 20-percent cost savings of $1.26B, most of which would come from the outsourcing of BOS functions between FY98 and FY03. Based on prior outsourcing experience, projecting an average 29-percent savings, this number is conservative.[5] However, because no common understanding of BOS exists, attempting to compare services between contracts and installations (or even among the Services) to accurately identify what services are included or excluded is extremely difficult. For example, the Army developed the Service Base Costing methodology (reflecting spending, not budgets) to better understand where its installation support money was being spent. A subsequent cost study examined 2 years of spending data in 95 different base service areas (both contracted-out and organic) at every Army installation. Analysis of these data performed by the Institute for Defense Analysis showed, "There was no systematic tendency for increased contracting to be associated with reduced costs."[6]

In contrast, the Air Force is boasting of many successes coming out of its A-76 competitions. After 1,399 competitions in 10 years, it has claimed a cost avoidance of more than $9B, manpower reductions of more than 37,621 full-time equivalents, and an average 38-percent cost savings (regardless of whether the work was awarded in-house or contract).[7] Table 1 illustrates some examples of BOS manpower savings.

Base	Pre	Post	Savings	Decision
Patrick (FY98)	118	69	42% ($2M)	In-house
Wright-Patterson (FY98)	503	254	50% ($14M)	Contract
Vandenberg (FY98)	211	142	33% ($3M)	Contract
Columbus (FY97)	341	227	33% ($6M)	In-house
Tyndall (FY97)	1,034	666	36% ($18M)	Contract
Laughlin (FY96)	278	187	33% ($6M)	Contract
Goodfellow (FY94)	277	176	36% ($1M)	In-house
Niagara Falls (FY90)	117	75	36% ($2M)	Contract

Table 1. BOS A-76[8]

Another problem in measuring cost savings (single BOS contracts for multiple base services) is the lack of a requirement to do so once a commercial activities study has been completed.[9] Moreover, since contracts are continually being modified and changed, the cost data from initial commercial studies quickly become obsolete. Indeed, the total costs of outsourcing are difficult to measure for other reasons as well. For example, a study by RAND found, "Because outsourcing influences management and monitoring costs, long-term investment needs, and the strategic focus of the organization, in addition to the short-term direct costs, its overall costs and benefits must be carefully evaluated."[10] Nevertheless, the study also demonstrated that the development of long-term partnerships does not require more people or time than managing large numbers of (less trusting) arms-length relationships but is likely to require a more professional and highly trained staff.[11]

In short, this lack of common understanding, within DoD, of what BOS is and how it can be measured and priced makes it hard to validate and justify claims of savings and generate greater support for expanded BOS outsourcing. Yet, despite these problems, a very important consideration of BOS is that each base or installation is unique in terms of its mission, infrastructure, location, and many other factors. Therefore, decisions about what activities to outsource and how to arrange the BOS service area groupings should be carefully tailored around the unique requirements of each installation and its mission. Likewise, it is essential that serious attention be directed to establishing the optimal government organization to perform program management and contract administration after the contract is awarded.

Recurring BOS Program Management and Contract Administration Problem Areas

In its guide, *Best Practices for Contract Administration,* the Office of Federal Procurement Policy (OFPP) cited several weaknesses in contract administration practices. Some of these included improperly trained officials' performing contract oversight, unclear roles and responsibilities of technical representatives, unclear statements of work (SOW) that hinder contractor performance, lack of a well-defined relationship between the contracting officer (CO) and program personnel, inadequate surveillance and monitoring of contracts, and contracting officials' allocating more time to awarding contracts than administering them.[12] Moreover, a RAND research brief argues, "Without significant managerial and organizational changes, the Pentagon will have a difficult time applying the lessons it has learned in these initial competitive-sourcing experiences to large segments of its uniformed and civilian work force."[13] Indeed, these kinds of problems can often be traced back to weaknesses in how the government team was selected, organized, educated, and trained. In turn, these problems have led to poor work statements, inadequate quality assurance surveillance, and difficulties in contract administration.

Government Team. There is no standard government structure to manage BOS contracts. Even so, based on the greater size, complexity, and diversity of BOS contracts, it is essential to have a well-educated, trained, and experienced team of cross-functional experts knowledgeable in commercial industry philosophies and practices. These are foundational to efficient and effective BOS management. Strong teamwork and partnering must occur both internally (one team, one goal, one voice) and externally between the government and the commercial-service provider. Unfortunately, the traditional Air Force organizational structure, culture, and functional specialization are resistant to this.

In fact, the Defense Science Board stated that one of the main impediments to outsourcing and privatization is the "resistance of the DoD culture to fundamental change."[14] Influenced by the bipolar Cold War experience, military warfighter thinking has been focused on readiness and the ability to carry out successful military operations—cost-consciousness and process efficiencies have taken a backseat. To support this Cold War thinking, the military built a *stovepipe* system of functional specialization (for both officers and enlisted) that has remained largely unchanged since World War II. Hence, critical in-depth knowledge and appreciation of commercial philosophies and business practices are quite foreign to most *blue-suiters.* An article in the Air Force Logistics Management Agency's *Issues and Strategy 2000: Contractors on the Battlefield* is especially critical in addressing the need for change:

> The time has come for military officers to stop rowing against the tide and plunge into the world of privatization . . . . The uniformed military needs a vastly expanded pool of well-trained professionals . . . to be effective, these military brain trusts *must* have true expertise in real-world military operations, public sector privatization lessons learned, federal law, and policy issues, as well as a thorough knowledge of commercial capabilities in the private sector.[15]

The article goes on to suggest that, instead of sending our best and brightest officers to intermediate and senior service schools, it might be better to send them to institutions such as the Wharton School of Business. This would be followed by internships with cutting-edge businesses whose success is centered on information management, outsourcing, and a complex web of suppliers.[16] The bottom line is the government team—as it is currently educated, trained, and experienced—is ill-prepared to fully capitalize on the many opportunities that exist through commercially provided BOS services. Accordingly, one of the most urgent areas requiring this commercial understanding is base-level program management and contract administration.

It must be emphasized that the organizational structure created to manage BOS contracts varies tremendously across MAJCOMs

and between bases. Thus, the generic BOS management model discussed here will be the program management office (PMO). This generally includes a military officer (or civilian equivalent) program manager (PM) and deputy and staff consisting of functional specialists (for example, civil engineering, supply, or transportation), program analysts, financial managers, quality assurance evaluators (QAE), manpower and quality advisors, or others. The CO and other contracting administrators may or may not be part of the PMO but, in any case, should always work closely with the PMO on all phases of the contract.

A key aspect of effective BOS management lies in how the PMO is organized in terms of skills, specialties, grades, and numbers of people (military and government civilian mix). Indeed, a big problem with BOS management is the lack of an Air Force standard officer specialty to serve in the PM capacity. Thus, the typical PM may come from a variety of career fields and be assigned with little or no education or training in commercial industry practices or service contracting. There have been situations where officers from four different career fields (civil engineering, logistics plans, supply, and acquisition) were successively assigned to the same PM position. None had any formal education, training, or prior hands-on experience in outsourced BOS services. This lack of experience, coupled with inconsistent directions to the contractor, led to serious disagreements and broken trusts that ultimately resulted in the contractor's winning a sizable lawsuit against the Air Force.

Likewise, other members of the PMO (usually enlisted or civilian functional specialists), though very experienced in their core specialties, often have little experience dealing with contractors using commercial practices. Also, when several single base services are consolidated into one large BOS contract, a PMO's responsibilities and span of control quickly grow in size and complexity. Add to this increased requirements for quality assurance, contracting, manpower, finance, legal, and multiple end-user customer requirements, along with contractor and subcontractor technical and management issues, and the job can become overwhelming. Management difficulties in bundling multiple, single-service contracts into a single, large BOS contract are underscored by an audit by the Air Force Audit Agency (AFAA).

In this case, five contracts supporting 22 base organizations were combined into one contract valued at $35M. The key problems were:

- Due to of the magnitude of the consolidated acquisition, the PM was not fully prepared to monitor the fund status for the numerous organizations receiving support.
- Contracting personnel had reserved, competed, and awarded the contract to a small business. Consequently, the PM could not adequately assist contractor personnel who were inexperienced with maintaining the multitier cost schedules necessary to accurately report operations.
- The quality assurance director did not implement an effective quality assurance plan. Functional area chiefs (FAC) did not always report or document contract surveillance. FACs did not promptly develop and submit functional area surveillance plans or nominate quality assurance personnel.[17]

In this example, the PMO, contracting office, and quality assurance office were not working together as a single, unified team.

In building an effective PMO, there are some fundamental questions to be answered, such as:

- What kind of PMO organizational structure will work best based on the types and numbers of consolidated services and base mission?
- How does one effectively involve and integrate the different base functionals, end-user customers, QAE, and contracting officials to carry out cradle-to-grave BOS program and contract management?
- Who is ultimately going to be in charge and responsible for bringing these diverse elements together?

Based on the diverse workload and associated management complexities, it is important that a single PM be responsible for overall BOS management. Such unity of control is central to efficient and effective base-level BOS support to the warfighter. An important question that remains unanswered, however, is, what career field is best qualified to manage the unique, multifaceted skills BOS demands?

PWS Development. The OFPP says the PWS should describe the specific requirements the contractor must meet, standard of performance for the required tasks, and level of quality the government expects the contractor to provide. However, it should not include detailed procedures that dictate how the work is to be performed. Instead, it should center on what is to be performed.[18] Certainly, an accurate, complete, and well-written PWS is probably the most critical element for ensuring the government customer gets what it pays for. Yet, stories still abound concerning poorly written, ambiguously worded, and unclear old-style statements of work. Again, the causes for these problems are rooted in the traditional differences between the government and commercial ways of doing business, coupled with not enough education, training, and reinforcement to transition away from the military approach. Military-based (MILSPEC/MILSTD) *how to* technical orders are very different than commercial industry's flexible, ever-changing practices. Learning to speak the same language has been a slow process as the following examples illustrate.

An AFAA audit of custodial services found "Personnel did not establish custodial standards . . . 22 buildings . . . received, but did not qualify for, daily cleaning services."[19] Revising the contract to meet current standards of the Air Force Civil Engineering Standards Agency could save nearly $400K over 6 years.[20] Similarly, a Government Accounting Office (GAO) study of BOS contracts at ten DoD installations identified "a well-defined performance work statement is the key to meeting these [results-oriented] requirements and preventing excessive modifications to contracts and unanticipated cost increases."[21] On the positive side, as the government shifts its emphasis from what and how the work is performed to results and outcome, improved PWS should result.

Quality Assurance Evaluation. At the heart of measuring and documenting how well the contractor is performing (both negative and positive incentives) lies the QAE function. Properly performed QAE is essential to enabling the PM and CO to accurately assess all aspects of contract performance, including operations and maintenance, business management, and technical and engineering performance. However, once again, recent experience has shown that government QAE oversight of contractor work is deficient in a number of ways. A recent AFAA audit of a housing maintenance contract found "the quality surveillance plan (QASP) was not properly developed and the QAE did not correctly document all inspections."[22] Accurate and complete QASPs and documentation of inspection results are essential to effective contract administration and good working relations with the contractor.

Trust is another key element of QAE. A RAND study on commercial practices in facility management (FM) found that the degree of mutual trust between the FM service buyer and seller determined the potential for mutual gain. Without trust, the relationship tends to be adversarial, and the focus is on close control with a reliance on many QAEs to ensure execution. Consequently, the relationship is typically short-term with frequent contract rebids and changes in providers.[23] This is not too different from the way DoD has traditionally carried out QAE, and it needs to change to become a cooperative partnership based on shared goals and outcomes.

Another important aspect about QAE is that too much monitoring of the contractor's performance can be costly. A 2000 RAND study on strategic sourcing found:

> Customers may have a strong compulsion to track many different dimensions of operational performance and cost, feeling that it is necessary to maintain control and verify that their providers are achieving the agreed-upon level of performance within the specified budget.[24]

However, this control comes at a price since, in the end, the government customer pays for all information used to monitor service providers (for example, contract data requirement lists) and the time spent examining this information. Therefore, customers hurt only themselves by requesting any information that is not essential for making important decisions.[25]

Contract Administration. Once the PWS and QASP have been written and the contract source selection made, it is the quality of contract administration that ultimately determines the success or failure of outsourced BOS. Of all the members of the government program or contract team, the COs probably have the most influential role. Based on their warrant to obligate government funds, they have a special responsibility to ensure the government gets all the services for which it has contracted and paid. Indeed, they are the central players in developing commercial business plans and acquisition strategies and advising, training, and supporting the other government team members in carrying out BOS management. Since they are the contract experts, they are relied on more heavily to ensure others become knowledgeable about commercial industry practices and changes to acquisition and contract requirements.

Nonetheless, these high expectations may be unrealistic for several reasons. First, the normal, heavy contracting workload makes it difficult for COs to keep themselves fully apprised of the latest acquisition reforms, much less find time to train the PMO. Second, the government typically does not provide training on ever-changing commercial practices and how they might influence the customer. Third, depending on the complexity of the service area, a CO may not have the technical background necessary to provide advice on military versus commercial practices.

In any event, it is essential that the contracting office work closely with the PMO every step of the way. Together, they must ensure all parts of the source selection and follow-on management (for example, PWS, QASP, and incentives) are fully integrated, completely understood, and properly executed by all parties, including the contractor.

Regarding future outsourcing, as the size and number of outsourced BOS contracts increase, the responsibilities of the contracting office and CO are certain to grow. However, in making the transition to BOS, COs have a new ally. Of growing importance is the role of manpower and organization (MO) as an ongoing advisor or full member of the PMO. The MO is expected to play a key role in educating, training, facilitating, strategic planning, and guiding the development of performance metrics for BOS contracts. Following the integration of the old total quality management program into the MO career field, they now have responsibility for planning, advising, and facilitating organizational and functional process improvements, productivity enhancement studies, commercial industry best practices, wartime manpower requirements support, and others. The MO is also the focal point for performance management planning at the wing and MAJCOM levels.[26] Thus, the MO should be relied on to facilitate the integration of strategic performance goals of the warfighter with all the base support functions, no matter who provides the service (contract or most efficient organization [MEO]). Moreover, this could help encourage the cultural paradigm shift to seamless integration of commercially provided BOS services.

Improvements in Acquisition Reform and Air Force CS&P Policy

> *It is the policy of the Department of Defense that, in order to maximize performance, innovation, and competition, often at lower cost, performance-based strategies for the acquisition of services are to be used wherever possible . . . . Those cases in which performance-based strategies are not employed should become the exceptions.*
>
> **—J. S. Gansler**

Services account for nearly half the nearly $200B the government spends annually through contracts.[27] Over the last 7 years, many improvements have been made to the statutory and regulatory structures that oversee procurement policy. In this regard, the OFPP has been pursuing acquisition reform to ensure full implementation of key practices to move the government closer to the commercial model:

- Making contractor performance a substantial factor in contract administration and source selection
- Encouraging contractors to innovate in deciding how to perform the work and tying payment to performance
- Using new contracting tools to obtain up-to-date technology and better prices[28]

Performance-Based Service Contracting

Before implementing these changes, in 1994, the OFPP sponsored a performance-based service contracting (PBSC) project to test PBSC methods on contracts for recurring services (that were not performance-based) and measure the impact of PBSC. The goal was to test the hypothesis that PBSC saves money and encourage contractor performance that better supports mission attainment. Twenty-seven agencies and four industry groups, representing more than 1,000 companies, endorsed the project. Overall, 26 contracts ($585M) from 15 agencies due to expire were resolicited using PBSC methods. The project's findings were based on before-and-after comparison and measured effects on price, performance, competition, audit workload, and procurement lead time. [29] The results were as follows:

- Price: on average, contract price decreased by 15 percent.
- Performance: customer (agency) satisfaction with the contractor's performance improved more than 18 percent. Ratings were obtained on five factors: quality, quantity, timeliness, cost-effectiveness, and overall performance. Significantly increased customer satisfaction was reported on all criteria.
- Competition: the average number of offers increased from 5.3 to 7.3.
- Audit workload: the total number of contract audits decreased 93 percent.
- Procurement lead time: average total procurement lead time increased by 38 days (from 237 to 275), and average solicitation-to-award lead time increased by 33 days (from 140 to 173). However, almost half the contracts experienced decreases or remained the same. The overall increase was expected since agencies had to develop new PWS, performance standards, and quality assurance plans and incorporate untried and significantly different contracting methods to apply PBSC.[30]

While the overall study results are impressive, a closer look at an individual project illustrates the kinds of improvement opportunity that PBSC offers.

The Navy applied PBSC to a $350M, 5-year contract for aircraft maintenance support for 357 T-34C and T-44A aircraft at 12 locations.[31] Important changes made by the Navy included:

- Separate tasks were defined in the PWs, and offerors fixed prices for each task. The minimum work statement read, "Provide Federal Aviation Administration (FAA)-certified personnel and facilities to perform scheduled and preventive maintenance in accordance with manufacturers' publications, FAA directives, and Navy maintenance engineering directives over a range of aircraft quantities."
- Measurable, performance-based metrics were then imposed (for example, aircraft 80-percent mission capable, ground abort rate less than 5 percent, and flight schedules met 100 percent).
- Streamlined acquisition procedures were used for the solicitation, and best-value award procedures were applied. A draft request for proposal was issued seeking industry inputs on alternatives to military specifications and standards. In response, many were deleted—some with no replacement—others were replaced with commercial standards (International Standardization Organization [ISO] for 9000 series), and mitigating language was applied to the remainder.
- Under the contract, the contractor is held to a high standard of performance and is empowered to use the best commercial practices and management innovation to continually improve performance.
- The contract provided both positive and negative incentives based on quantifiable standards. On the positive side, materiel management functions were turned over to the contractor. Materiel is purchased on a cost-reimbursable basis, but the contractor can earn a 15-percent incentive for cost avoidance. On the negative side, the contract is priced at a ready-for-training rate of 75 percent. If this rate is not met, the contract price is reduced proportionately (for example, a 60-percent training rate would result in a 20-percent reduction in contract price). This incentive encourages optimum contractor performance in a critical customer area.[32]

This conversion to performance-based contracting resulted in immediate savings of $25M from the previous nonperformance-based contract, and the Navy expects even more savings through positive and negative contract incentives.[33]

In light of PBSC's early successes, the *Federal Acquisition Regulation* (FAR) has been changed to include PBSC. FAR 37.601 defines the requirements of a performance-based contract as:

> Requirements described in terms of results required rather than to methods of performance of the work.
>
> Use of measurable performance standards (that is, terms of quality, timeliness, quantity, etc) and quality assurance surveillance plans.
>
> Procedures for reduction of fee or for reductions to the price of fixed-price contract when services are not performed or do not meet contract requirements.
>
> Use of performance incentives where appropriate.[34]

Likewise, senior DoD leadership has embraced PBSC. On 5 April 2000, the Under Secretary of Defense (Acquisition, Technology, and Logistics) directed all DoD departments and agencies to acquire 50 percent of all services, measured in both actions and dollars, in a performance-based manner by the year 2005.[35] In concert with this, the Assistant Secretary of the Air Force for Acquisition sponsored the Acquisition Reform Reinvention Team with the goal of revolutionizing Air Force service contracting. They developed policies, procedures, and tools to remove barriers to implementing commercial practices. They also created the Air Force Service Contract Advisory Group II, consisting of functional experts for the particular service and contracting personnel from all levels (Air Staff, MAJCOM, wing) and commercial contractors. Moreover, in June 2000, the Air Force issued the PBSA implementation plan outlining current policies, procedures, and initiatives. This included a massive education and training effort to ensure quality assurance personnel, the functional communities, and others, from Headquarters Air Force to individual Air Force installations, understood and began applying PBSC to meet the 50-percent 2005 goal.[36] These aggressive initiatives suggest that better quality, performance-based PWSs, QASPs, and contracts should result and lead to improved BOS management.

BRAG

To institutionalize PBSC, the Air Force had to overhaul procedures used to contract for services. Therefore, Air Force Instruction (AFI) 63-124, *Performance-Based Service Contracting,* was written to establish the framework and procedures for effective execution of PBSC.[37] It established the concept of the BRAG as the means to carry out PBSC. Established by installation commanders, the Business Requirements Advisory Group is, "A business solution team that consists of cross-functional personnel that plan and manage service contract outcomes to the satisfaction of its customers."[38] BRAGs plan and manage service contracts throughout the life of a requirement. Working together, BRAG members conduct market research, define requirements, develop the contract structure, and set up quality and surveillance approaches. In addition, the BRAG has responsibilities for acquisition planning, development, and performance management for new (including A-76 studies) and follow-on service contracts.[39]

One big advantage of the BRAG is its flexible organization that can be tailored to fit the needs of an individual base. BRAGs can also be centralized for regional, MAJCOM, or combined MAJCOM-type acquisitions.[40] For BOS contracts, this flexibility is essential. Moreover, the standardized structural framework of BRAGs that brings together the PMs, contracting office, manpower, legal, financial, and functional communities could help improve cooperation and coordination on the government side of BOS.

However, there are some downsides to the BRAG. The flexibility built into BRAGs can also lead to too little structure

concerning the roles, responsibilities, and boundaries of the different organizations. Moreover, the larger, more diverse, and complex the BOS, the greater the management challenges, leaving the question—who is in charge? The CO cannot do it, the MO cannot do it, and a functional specialist may not have the proper background, education, training, or experience to do it. Furthermore, AFI 63-124 does not address who can or should do it. Based on their extensive project management experience and the many similarities between procurement acquisition and services acquisition (for example, PMOs, integrated product teams [IPT]), acquisition officers may be a good choice. However, since they do not normally perform BOS-type, services-based acquisition and are not usually assigned at base level, more study is needed to see what role they could play.

In any case, senior Air Force leaders see the creation of BRAGs as a positive step toward implementing PBSC across the Air Force.

Leading-Edge BOS Program Management

The legacy of obsolete institutional structures and processes and organizations does not merely create unnecessary cost, which of course it does; it also imposes an unacceptable burden on national defense.

—Donald Rumsfeld

In step with the recent improvements in acquisition reform and Air Force-level CS&P policy guidance, innovative leading-edge BOS program and performance-management organizations have emerged and are moving toward building strategic partnerships between the government and commercial service providers.

ACC Program Management Squadron

The Air Combat Command (ACC) Program Management Squadron, located at Langley AFB, Virginia, has been in the outsourcing business since the late 1980s. The squadron is ACC's lead organization for directing and managing all aspects of operations, logistics, communications, and engineering for seven large-scale operations and maintenance contracts. The organization includes 134 military and civilians administering more than $840M in contracts and $3.5B in assets at 29 sites in the United States and 12 countries. The organization provides a unique cross-functional activity charged with program management of outsourced operational systems.[41]

These systems are operated and maintained through large-scale contracts supporting various government agencies in multinational environments. Overall responsibilities include planning, coordinating, managing, and budgeting services executed by contract or international support agreement. Other duties include contract management, performance certification, and assistance to other Air Force and ACC agencies in the development, program management, and administration of complex, large-scale contracts.[42]

This relatively flat organizational structure depicts seven major functional program and support divisions including civil engineering, computer-communications, logistics, surveillance, aircraft maintenance, plans and programs, and quality assurance. The program managers each receive support from the various functional areas and quality assurance rather than having these personnel embedded into the program management divisions. Other specialized support offices (information management, command data management, and financial management) are also located within the squadron.[43] The ACC Contracting Squadron provides contract administration. Based on the specialized nature and diversity of their contracts, the PMS maintains a balanced military and civilian mix to ensure program continuity and an infusion of new ideas and experiences.

Education and training are a top priority—assigned personnel receive a variety of on-the-job training, government continuing education, and training on commercial standards (for example, ISO 9000) and are also afforded the opportunity to earn master's certificates in areas such as project management and government contracting from George Washington University. This education and training is reinforced through writing PWS and QASPs for new and recurring source selections.[44]

For long-term acquisition planning, the PMS Plans and Programs Division performs strategic planning activities, prepares and coordinates acquisition planning, and heads new source selections and recompetitions.[45] One significant benefit of a separate division to study long-range issues (for example, mission evolution, commercial industry trends, and acquisition reform) is the program management personnel's ability to focus on current contracts.

The organization's management was very proactive in communicating information and strategies across programs that were well-supported by a robust, self-contained functional specialization support structure. Yet, they maintained a ready capability to contract outside help through consultants (for example, Army Corps of Engineers and specialized commercial consultants) when additional experience was needed. This *just in time* labor approach provided added capability at minimal cost.[46] The PMS has been transitioning to PBSC for new and recurring source selections.

The success of the ACC PMS is evident through growth in the number of ACC-wide programs within the organization. Also, the synergy gained from lessons learned and best practices within the different programs continues to benefit the squadron's success, making it a useful model for further study of BOS management.

AETC Pick-A-Base Concept

The Pick-A-Base (PaB) program is Air Education and Training Command's (AETC) strategic program for competitively sourcing BOS. The PaB concept grew out of Jump Start (a 1997 Air Staff initiative to identify potential competitive sourcing candidates) and AETC outsourcing lessons learned. Specifically, AETC found:

- Outsourcing done without a comprehensive plan leads to mission fragmentation—and multiple fragmented contracts and MEOs across the command.
- A-76 studies were very labor- and time-intensive, and transition to MEO or contract was turbulent.
- The larger the study, the larger the savings (for example, 301+ positions yielded an average 41-percent savings).

Based on these experiences, AETC decided to include as many base functions as possible within each A-76 study. It also combined existing contracts where possible. Together, these resulted in a reduction in the number of contracts at each base studied, which, in turn, meant larger BOS contracts that would attract world-class bidders and result in a higher class service. Thus, the PaB concept was born.[47]

Maxwell AFB, Alabama, is the first of five AETC bases to be competitively sourced under the PaB program. The four other PaB locations are Lackland AFB, Randolph AFB, and Sheppard AFB, Texas, and Keesler AFB, Mississippi.[48]

By actively incorporating PBSC principles, AETC is defining requirements in performance-based commercial terms and then monitoring contract performance using commercial methods. Accordingly, AETC is proactively building partnerships between the government and service providers. It does this by using modified, cost-reimbursement contracts to allow the sharing of savings (between the government and service provider) and through consolidation of varied facility management services.[49]

Since the PaB concept is so new, it does not yet have the benefit of experience to back up just how successful it will be. However, the initial numbers from the Maxwell experience, in spite of turbulence in awarding the contract, appear promising. The overall manpower savings will be more than 300 people, and a lean PMO staff (9 to 12 people) will be responsible for BOS management. This will include contracting, manpower, and functional specialists covering the various contracted service functions. Functional specialists will be expected to perform three main duties—functional and technical, performance management, and data analysis.[50]

Overall, the approach is sound, but there are still many questions that need to be resolved, such as:

- Should the PMO be structured differently for an MEO versus a contractor win?
- How will performance monitoring and risk-sharing be carried out?
- Where will the PMO staff come from?
- What kinds of education and training will be provided?
- Who will be in charge of running the PMO (that is, have authority, responsibility, and accountability)?

Thus far, some of the biggest AETC PaB successes are the aggressive command-wide shift to PBSC and the incorporation of BRAGs. AETC's thorough market research, performance-management focus, emphasis on building long-term relationships through strategic partnering with the contractor, innovative contract incentives, and risk-sharing are best practices. Another potentially successful area (though still untested) is the much smaller, streamlined government PMO to perform contractor insight versus the old QAE oversight.

AETC has put tremendous effort into developing a comprehensive PaB program and is committed to ensuring its success. However, it still needs a lot of help from the senior Air Force leadership to make this happen. In a recent briefing, the AETC Director of Contracting cited four needs to ensure PaB's successful implementation.

- A business strategy for competitive sourcing integrated at the Air Force/MAJCOM/base level
- A reassessment of small business roles
- Cross-functional cooperation starting at the top
- A system to make this all happen[51]

NASA-Patrick AFB: Joint Performance Management Office

The Joint Performance Management Office (JPMO), a National Aeronautics and Space Administration (Kennedy Space Center) and Air Force Space Command (Patrick AFB) partnership, was established for contact management of the Joint Base Operation and Support Contract (J-BOSC). These partnering efforts were focused on improving efficiencies and greatly reducing costs to support the nation's spacelift requirements while strengthening the reality of a Cape Canaveral spaceport. J-BOSC is a PBSC, awarded in October 1998, and covers a 5-year base period with one 5-year option valued at approximately $2.2B over the 10-year period.[52] It replaced 18 separate base-support contracts encompassing more than 160,000 acres and three geographically separated locations and saved $35M through the consolidation.[53] Figure 1 shows the projected savings between J-BOSC and separate contracts.

Military and civilian personnel from NASA and the Air Force staff the JPMO, which reports through an executive director to the 45th Space Wing and Kennedy Space Center board of directors. Consisting of senior management from both agencies (for example, financial, contracting, legal, operations and support commanders and directors), the board issues policy and guidance for the JPMO.

The JPMO structure is divided into five offices—Executive Management, Contracting, Staff, and Integration. Eighteen IPTs, consisting of JPMO members as lead, with contractor and stakeholders, provide a forum where new requirements can be discussed and contract issues resolved. The IPTs also provide regular customer feedback directly to the contractor, establish performance standards, and perform *contract insight* (versus the old-style notion of QAE oversight).[55]

To ensure unified operations, the JPMO incorporated the best practices of NASA and the Air Force to develop a single business system that includes daily operations procedures and a strategic planning system that complies with both NASA and Air Force policies. This system was certified ISO-9001 compliant in June 1999.[56]

Besides the huge, initial cost savings, the results of the consolidation have been enormously successful in improving BOS management. For example, earlier contracts required 200 people to perform contract oversight. Now the JPMO—using insight—requires only 40 NASA and Air Force civilian and military people to assess contractor performance.[57] In addition, both agencies have benefited from *one stop shopping* for customer service. When someone needs NASA support or Air

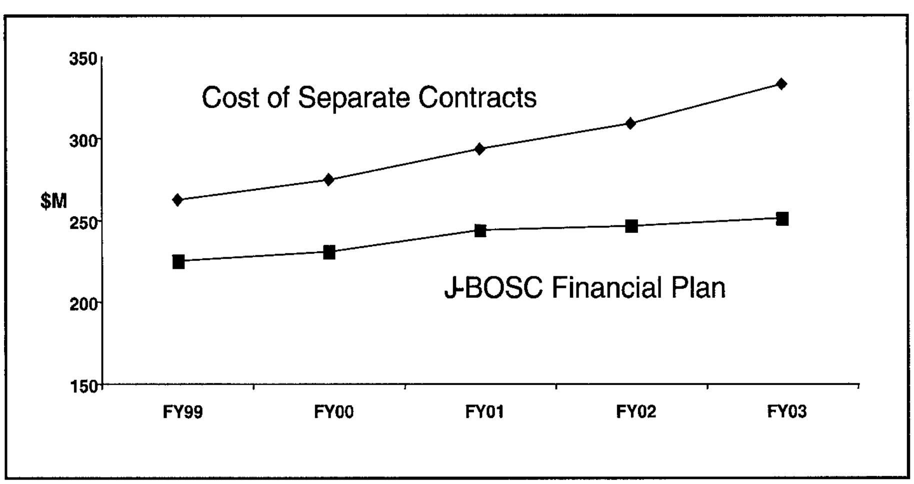


Figure 1. BOS Savings Estimates[54]

Force support, be it a government or commercial customer, only one number has to be called for assistance. Perhaps the most important improvement is the 24-hour-turnaround on the launch range. Consecutive launches within 24 hours of each other are now possible—this had never been done before JPMO was established.[58]

The increased efficiencies gained by J-BOSC have allowed the Kennedy Space Center and the 45th Space Wing to recapitalize and improve their infrastructure and initiative innovations to improve customer service and satisfaction. They also underscore that joint partnerships in the outsourced BOS arena can achieve winning outcomes, not only for the partners but also for the numerous customers and stakeholders and the service-provider contractor. The JPMO effectively communicates updates and announcements through the quarterly *Joint Update Newsletter* and a well-maintained website that contains a wealth of useful links, including contract, award fee, IPT, and customer web pages.

In summary, the innovative BOS management approaches illustrated above prove that CS&P can be successful. Similarly, many other DoD organizations have achieved comparable successes with their BOS outsourcing programs. Likewise, as more is learned about commercially provided BOS services and best practices are learned and shared with others, even greater BOS success can be expected.

Conclusion and Recommendations

Our success to date doesn't mean that our task is complete—on the contrary, so long as inefficient practices still exist—defense reform will remain one of my highest priorities.

—William S. Cohen

In conclusion, BOS contracting is a unique, complex, and challenging but vitally important Air Force CS&P program that will continue to grow. In its zeal to quickly implement outsourcing, the Air Force allowed many nonstandard approaches in program management and contract administration that led to problems and negatively impacted costs, efficiencies, and overall BOS performance. However, new Air Force-level CS&P guidance and improved acquisition practices such as PBSC and the widespread establishment of BRAGs suggest more BOS improvements will be forthcoming. Also promising are an increasing number of innovative, leading-edge BOS organizations that are benchmarking and sharing best practices with others.

In assessing the progress in BOS management against the four principal Air Force CS&P goals, one gains a little clearer picture of where we have been and where we still need to go.

Sustain Readiness. At this time, it is too early to say, but if the CS&P promise to free military members to concentrate more on their core competencies holds true, it could provide some badly needed relief. However, there are many unknowns, and much more study lies ahead for the manpower, personnel, and other functional communities.

Improve Performance and Quality by Doing Business More Efficiently and Cost Effectively. All the CS&P evidence suggests that, whether the in-house MEO or contractor bid wins, the service becomes leaner and more efficient. Yet, more study is needed to determine the optimal PMO structures and staffing for monitoring either MEO or commercial contractor performance and ensuring efficiencies and performance can be maintained and improved over time.

Generate Funds for Force Modernization. Available Air Force cost data suggest that outsourced BOS is generating significant savings that can be applied toward modernization. Still, many problems must be resolved to improve and continue this positive trend. DoD-wide, there needs to be a common definition and framework for BOS along with a standardized cost-accounting system that can generate and track accurate, comparable cost data. Also, it must be remembered that, over time, changes in mission requirements, technologies, competitive pressures, politics, and a host of other factors could impact these savings in unpredictable ways.

Focus Personnel and Resources on Core Air Force Missions. Great care must be exercised to maintain the right balance and mix of highly skilled and motivated airmen necessary to fully meet the needs of the new expeditionary aerospace force. When all is said and done, it is essential that the many promises of outsourced BOS be realized through more effective support to the end-user—the warfighter.

Overall, the Air Force is heading down the right path with BOS CS&P but still has a long way to go. The following recommendations are offered to help facilitate greater cost savings and improved BOS management.

- The Air Force must be aggressive in ensuring the rules and tools for successful implementation of acquisition reform and CS&P policies (for example, PBSC) are known and applied everywhere and at all levels. This will require senior Air Force leadership to set the tone and lead the way. Moreover, continued support from MAJCOMs and various CS&P support and advisory agencies to base-level BOS managers will help ensure outsourced BOS services are successful.
- The Air Force should reevaluate and restructure the PMO organization and practices to optimize its efficiency and effectiveness but leave it flexible enough to be tailored to best meet a base's support needs and mission requirements. The question of who is in charge still needs to be answered. The BRAG concept is a good start, but it offers no answers on how to organize and build an effective PMO team.
- Greater emphasis on education and training on commercial philosophies and business practices needs to take place at the base-level PMO. This should result in a more cohesive and capable government (military and civilian) team that can strategically partner with commercial service providers for improved BOS performance at a lower cost. It will also require a greater commitment from senior Air Force leadership to provide funding and opportunities for world-class education and training to help build a motivated and professional PMO staff.
- The Air Force should reevaluate officer, enlisted, and civilian career-field job descriptions and core competencies against those required for BOS management. The growing demands of outsourced BOS services demonstrate that the functional career fields now require balanced sets of competencies and skills (core warfighting and contracted mission support) to be most effective both at home station and while deployed.
- Because commercially supplied BOS services will become the norm in the future, the Air Force must find new ways to influence a cultural shift (within the military and civilian work force) to actively foster and build long-term relationships with world-class BOS service providers based on mutual trust. Once again, the vision, leadership, and example must begin at the top and permeate through the MAJCOM functional staffs down to the base-level environment.
- There must also be a shift in emphasis from QAE (oversight) toward performance management (insight). This implies a significant reduction in QA staffs that currently perform oversight and a corresponding shift

based on greater trust and reliance on the contractor's quality control and improvement processes.

- Improvements and refinements will be required in how incentives (for example, award-fee programs and award terms) are managed to attract, secure, and retain only the best service providers. Furthermore, it must be remembered that this is a two-way street. To attract the best service providers, the Air Force needs to prove itself a trustworthy and reliable buyer of BOS services.

The success of CS&P and outsourced BOS services is important to the future of the Air Force. If done right, better managed BOS services can lead to significantly greater cost savings for future procurement, more efficient and effective base support business practices, and improved readiness—all of which can contribute to increased military capability and better support to the warfighter.

Notes

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EXPLORING THE HEART OF LOGISTICS

In-Place Readiness Spares Packages

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Bases with in-place readiness spares packages (IRSP) can, and do, have base-requisitioning objectives (RO) less than their total wartime requirement (TWR). (The base RO is the sum of the wartime RO and the peacetime operating stock [POS] RO and should never be less than the TWR.) As a result, these bases may not have the spares on hand needed for a conflict.

Some Air Force bases are designated as *fight in place* bases; in other words, they do not deploy to a theater of operations. Instead, they fly their wartime sorties from home station. As a result, these bases have an IRSP instead of a mobility readiness spares package. These IRSP bases are given a TWR for each recoverable item spare (XD3 national stock number [NSN]) loaded at the base, which should be at least equal to the base's RO (the RO is actually one greater than the TWR if there is a positive readiness-based level [RBL]). This TWR includes the sum of the POS, which in the vast majority of cases is the RBL minus one, and the IRSP level.

TWR = IRSP level + (POS level - 1)
or
TWR = IRSP level + (RBL level - 1)

The TWR is set at the USAF Readiness Spares Package (RSP) Review Conference. The IRSP level authorization is determined based on the POS authorization; that is, the IRSP level is set such that IRSP plus the RBL (minus one) equals the TWR. Some exceptions can occur when the base does not receive an RBL for an item that also has an IRSP level, such as for two particular types of RBL-identified problem items. For the purpose of simplicity, this article will assume the RBL is the POS quantity used in the offset calculation, although that may not always be the case. Regardless, the analysis was not affected by the exceptions. For the exceptions, merely substitute the RBL with the base-computed, repair-cycle demand level. The IRSP level does not vary when the kit is fielded, even if the RBL subsequently changes. RBLs are computed quarterly and, therefore, vary. As a result, if the RBL decreases on a future date, the base's RO declines and could decline below the TWR. In determining the IRSP base's RO, the RBL in effect at the time of IRSP level computation is subtracted from the TWR to determine the IRSP authorization using the following formula:

IRSP level = TWR - (RBL - 1)
where (RBL - 1) is known as the offset quantity

IRSP Computation Example

The following example will be used to explain both the current problem and suggested alternatives for addressing the problem. Recall that the IRSP authorization is set to the TWR minus the RBL minus one. Also, the IRSP authorization is set at the RSP review, which could occur up to 9 months prior to fielding the IRSP. That IRSP level is then used for at least a year while the kit is fielded. With current funding shortfalls, some of today's kits have remained loaded in the field for nearly 2 years. The RBL can and does change quarterly. For example, assume the following:

TWR = 5
RBL = 4 therefore,
Offset = 3 ((RBL - 1) or (4 - 1 = 3)) and
IRSP = 2 ((TWR - (RBL - 1)) or ((5-(4-1)) thus
RO = 6 (RBL + IRSP) or (4 + 2)

The base RO of six is the sum of the RBL and IRSP level, four plus two, and exceeds the minimum need, the TWR of five.

If the RBL changes, say from four to two, then the base's RO becomes four, which is less than what is needed, the TWR. In today's system, the IRSP level remains at two, and the base RO becomes four. This means the base may not be able to meet its wartime sortie and aircraft objectives and cannot, under current policy, requisition up to its TWR. The base RO should remain at six; therefore, under ideal circumstances, the IRSP authorization should increase to four to make up for the lower RBL, something that does not occur today. So the *optimal system* would update the IRSP quantity as the POS level changes.

If the POS level changes to five, the base RO becomes seven, more than the TWR plus one and, therefore, more than the base needs. The base RO should remain at six, and the IRSP authorization should decrease to one because of the larger RBL level.

Reason for POS Offset

Since bases with IRSPs fight in place, there is a definite need for a POS offset. There are 13 IRSPs in the Air Force today, 6 in the Pacific Air Forces (PACAF) and 7 in Air Mobility Command (AMC). Since the bases with IRSPs fight in place, they can use any on-hand stock at their bases to meet the 30-day (60 for strategic airlift) wartime tasking. Some POS should be available at the start of hostilities, and the Air Force should not have to buy additional wartime spares to cover needs that can be filled by these available peacetime spares. The Air Force uses a simple rule of thumb to determine the amount of the POS level that is expected to be on hand. Only on-hand stock is looked at because current policy assumes no depot resupply for the first 30 days

(60 for strategic aircraft) of the war. The rule of thumb for computing on-hand stock is the POS level minus one, effectively the RBL minus one for most cases. Subtracting one accounts for the fact that one of the spares filling the POS level will not be available because it will be in the not-reparable-this-station (NRTS) pipeline or on order from the depot (the order and ship time [O&ST] pipeline). Thus, to avoid understating the IRSP quantity, an accurate offset would be to compute the NRTS pipeline quantity plus the O&ST pipeline quantity and subtract that sum from the POS level. Empirical evidence shows that about 90 percent of the NRTS, plus O&ST pipeline quantities, are less than one. Hence, the simple rule of thumb is to subtract one (a reasonable estimate for the rounded value of the NRTS plus O&ST pipeline quantity) from the POS level.

That is the theory behind the offset and its calculation, but why bother? Is there enough of a savings to require this computation and build a system to update it? The answer is, yes, there is a significant potential for reducing the overall spares budget by using POS assets to offset IRSP requirements. For the PACAF kits evaluated, which represent 6 of the 13 IRSPs in the Air Force, about $9.7M in POS levels is available as offsets. For six of the seven AMC IRSPs, there is nearly $44.8M in POS levels available as offsets. The Air Force can afford to make system changes to continue reducing its overall gross spares budget by the amount offset in the PACAF and AMC IRSPs.

Optimal Solution

The Seamless Supply Working Group (SSWG) developed an RSP initiative that addresses the system changes needed to resolve this problem. It proposes an interface between the Weapons System Management Information System (WSMIS) and the D035E/RBL system that will update the offset data, recompute IRSP authorization quantities, and then push the new IRSP levels to the bases. This is the optimal alternative to today's system but requires system changes. It is important that the Air Force Requirements Management System (RMS), or D200A, also reflect the accurate total requirement as well as an accurate segregation of the source of that requirement, as either POS or war reserve materiel (WRM). The two requirements are treated differently at the wholesale and retail levels. The WRM requirement is additive and pushed to the bases in RSPs, while the POS requirement is usually computed and pushed via RBLs. The retail system uses a higher priority to replenish WRM, so it is important for the requirement to be accurately stratified in RMS.

Initially, eight potential solutions to the problem were developed, including the optimal solution, and were briefed to the Air Force Supply Wartime Policy Working Group (AFSWPWG). The AFSWPWG then tasked the Air Force Requirements Team to further analyze four of the eight options.

Alternatives

With today's system, the offset and, therefore, the IRSP authorization are fixed for the period of time the IRSP is fielded. Since the RBL can change, there is no guarantee the base's RO will be accurate (equal to the TWR plus one for NSNs that have a positive RBL).

Alternative 2: Update Offset—The Optimal Solution

The second method, the optimal solution, is to update the offset and, therefore, the IRSP authorization as RBLs change. This method would ensure an accurate base RO and should be the long-term solution to the problem. However, the Air Force also needs a short-term solution, one that does not require any major system changes. The remaining six alternatives are described below and are meant as short-term solutions.

An adjusted stock level (ASL) is a quantity that can be loaded at the base to influence that base's RO. A minimum ASL indicates to the RBL model that the base should have a POS level no less than the minimum ASL. A fixed ASL would instruct RBL to allocate a POS level exactly equal to the fixed quantity, no more, no less. Finally, a maximum ASL sets the maximum allowable POS level; RBL will not allocate more than the maximum ASL quantity. If a sufficient worldwide requirement, as computed by RMS, exists, then RBL will honor the ASLs. If there is not a sufficient requirement to honor the ASL quantity, then the RBL model flags the NSN as a problem item and, using a heuristic, allocates whatever requirement exists to best reduce expected back orders.

Alternative 3: Minimum Adjusted Stock Level—Additive

This option requires the base to load a minimum ASL equal to the RBL used at the time of IRSP computation, upon fielding of a new IRSP. The minimum ASL will give the base a level at least equal to the offset plus one, thereby guaranteeing the base RO will at least equal the TWR plus one.

> **Example: TWR = 5, RBL = 4, Offset = 3, IRSP = 2 and RO = 6.** The base will set a minimum ASL equal to four (equal to the RBL or the offset plus one). If the POS level increases to five, then the RO increases to seven. The minimum ASL prevents the RBL allocation from dropping below four (or RCDL for the exception cases); therefore, the RO will remain at six.

This option guarantees the RO to be at least equal to the TWR plus one and allows a base to receive extra POS levels if its demand increases. It is also an easy solution to implement. However, the worldwide requirement (at least the base RO) will increase. In the example, if the POS level increases to five, the IRSP authorization should decrease to one, but with this method, the IRSP authorization remains the same at two. So the RO of seven is one unit too large. Whenever the POS level increases, this option will provide a higher RO than required. Two other disadvantages include the need for manual recomputation of ASL quantities annually when new IRSP kits are fielded and the danger that non-IRSP bases could have their POS levels reduced (transferred to the IRSP bases since RBL cannot allocate base levels that, when summed, exceed the worldwide requirement as computed by the RMS). The latter disadvantage could increase expected back orders and increase RBL-identified problem items.

Alternative 4: Minimum ASL—Nonadditive

The base or the D035E/RBL programmer would load *pseudo* ASLs, those that will act the same as normal ASLs within RBL except they would not be passed to the RMS to become an additive to the worldwide requirement. Since this solution need apply only to IRSPs, there would be no buy requirement. Therefore, it would only affect the Air Force repair requirement, which is currently a fixed number of standard deviations computation. Therefore, the ASL quantity may not have a significant effect on any portion of the worldwide requirement.

This option has the same advantages and disadvantages as the previous option. However, this option would tend to create unsupportable base levels, levels for which there is no worldwide requirement. The levels would be unsupportable because the RMS would not receive the ASL quantities from RBL for inclusion in the RMS computation; therefore, RMS may not compute a large enough requirement to support the levels.

Alternative 5: Fixed ASL

This option is the same as Alternative 3, only the base would load fixed rather than minimum levels. This guarantees the base RO is at least the TWR and prevents additional requirements growth. Our example will illustrate:

> **Example: TWR = 5, POS = 4, Offset = 3, IRSP = 2.** The base would load a fixed ASL equal to four, making the RO equal to six. If pipeline changes would generate a POS level increase to five, the fixed ASL will prevent RBL from allocating an additional level, maintaining the POS level at four and the RO at six. If pipeline changes would generate a POS level decrease to two, the fixed ASL will hold the RBL level at four, and the RO will remain six.

A fixed ASL incorrectly suppresses the base's RBL whenever it would exceed the TWR as a result of additional demand. There were several cases of that occurrence, which were highlighted during the analysis of the actual IRSP data.

Alternative 6: Set the IRSP Equal to the TWR—Maximum Level

The next three options set the IRSP authorizations equal to the TWR. That would ensure the base RO meets the TWR, but the worldwide requirement would increase by the amount of the peacetime levels that can be offset. The first version of setting the IRSP equal to the TWR sets a maximum level of zero for the POS level, thereby preventing RBL from allocating any POS level at all.

> **Example: TWR = 5, POS = 0, Offset = 3, IRSP = 5 and RO = 5.** Regardless of the POS level RBL would generate, the maximum ASL would ensure the RO remains at five.

This option will ensure the RO equals the TWR and the IRSP base would not *steal* a POS level from another base. Setting a maximum level of zero does not affect the worldwide requirement, only how the requirements are allocated to the bases. It does restrict the IRSP base from getting additional POS levels if pipeline changes warrant.

Alternative 7: Set the IRSP Equal to the TWR—Let the POS Float

This alternative allows the IRSP base to receive POS levels.

> **Example: TWR = 5, POS = 4, Offset = 3, IRSP = 5 and RO = 9.** Like the previous alternative, the IRSP is equal to the TWR, but the base is allowed to receive POS levels as the demand and pipeline data warrant within RBL.

This option ensures the RO is at least equal to the TWR and allows a base to earn a POS level. However, it increases the worldwide requirement and overestimates the RSP requirement. The base RO should actually be six (TWR plus one), and this option results in an RO of nine.

Alternative 8: Set the IRSP Equal to the TWR—Decrease POS

Decrease the amount of worldwide requirement for RBL to allocate by the offset amount and allow RBL to allocate the remainder optimally to reduce worldwide EBOs. This option ensures the worldwide requirement does not grow.

> **Example: TWR = 5, POS = 4, Offset = 3, IRSP = 5, then the RO = 9.** Like the previous example, this results in the correct base RO regardless of the POS level, and the base can earn POS levels based on its demand and pipeline data.

This base earned a POS level of four after the worldwide POS requirement was reduced by three, the offset amount. This method ensures the RO is at least the TWR, does not inflate the worldwide requirement, and allows the IRSP base to earn extra POS levels in later RBL computations. The disadvantage of this approach is that it increases the RSP portion of the worldwide requirement by the POS offset amount (although the same amount is reduced from the POS requirement). That could improperly affect repair and shipping priorities. This approach will also take levels from non-IRSP bases (the offset amount subtracted from the worldwide requirement results in fewer levels allocated to non-IRSP bases). The biggest disadvantage is that this is a long-term approach. It requires system changes. And if changes are to be made, they should be for the optimal option.

Identifying a Solution

Alternatives for Further Analysis

Alternatives were briefed to the AFSWPWG in May 2000; they discarded half of the alternatives as not being viable because of their negative impact on the requirements system. They asked for further examination of the following options: Alternative 2, Update Offset—the Optimal Solution; Alternative 3, Minimum ASL—Additive; Alternative 5, Fixed ASL; and Alternative 7, Set the IRSP Equal to the TWR and Let the POS Float. Comparison is made to the actual impact—using current POS levels data and RBL levels from April 2000—on existing IRSPs for these options.

Offset Values as of June 2000

Tables 1 and 2 summarize the dollar value of the offset for the 431 PACAF and 829 AMC NSNs with sufficient POS levels to offset at least part of the IRSP. The PACAF gross requirement reduction at the initial fielding of the kit was $19.6M. The offset amount is the amount entered in WSMIS at the time of the RSP review. It is doubtful the PACAF offset amount was accurate when it was entered in WSMIS since the PACAF offsets were generally too high. The new offset values were computed using April 2000 RBL data. It was expected there would be an even spread with some new offset values being lower than the older ones, some equal to the older offsets, and some greater. In 70 percent of the cases, the new offset value was much less than the old one, leading to the conclusion that the original offset values were too high. This could have been caused by inaccurate computation of offset values by the Standard Base Supply System or forecasting offsets using old, inaccurate data. Therefore, a better estimate was provided of the amount of POS that could be offset in the fourth column. The estimate is based on the actual RBLs as of April 2000, yielding $9.7M of POS levels for PACAF that could have been offset. For AMC, the total is $44.8M. Of the 1,260 NSNs examined in the tables, 383 of them had base ROs less than their TWR.

Weapons System	Base	Offset in WSMIS $M	Estimate of Actual Offset $M	Number of NSNs with Offset
E-3	Kadena	8.2	1.0	150
KC-135R	Kadena	3.4	1.8	87
E-/KC135R Common NSNs	Kadena	0.2	0.1	5
F-16	Kunsan	5.4	4.0	78
F-16	Osan	0.6	1.5	40
A-10	Osan	0.8	0.8	53
F-16/A-10 Common NSNs	Osan	1.0	0.5	18
Totals		**19.6**	**9.7**	**431**

Table 1. Amount of Offset PACAF

Weapons System	Base	Offset in WSMIS $M	Estimate of Actual Offset $M	Number of NSNs with Offset
C-5	Dover	13.3	18.4	196
C-5	Travis	9.1	11.2	132
C-141	McGuire	3.5	6.9	91
C-141 (x2)	McChord	5.8	6.7	265
C-17	Charleston	1.1	1.6	145
Totals		**32.8**	**44.8**	**829**
Air Force Totals	**AMC and PACAF**	**52.4**	**54.5**	**1,260**

Table 2. Amount of Offset AMC and USAF Totals

Comparison of Alternatives

Tables 3 through 5 provide the individual kit and major command (MAJCOM) total comparisons for each of the four alternative POS offsets. For example, Table 3 shows the results for four PACAF IRSPs, including the Kadena KC-135R IRSP. Using optimal alternative 2, at Kadena, the IRSP cost would increase by the $0.02M in repair cost. There were 53 NSNs whose base RO would increase by 76 units and 5 NSNs whose RO would decrease (that is, RBL previously allocated levels larger than the original offset). Note that Alternative 7, Set the IRSP Equal to the TWR—Let the POS Float, increased kit cost the most because this option can never decrease the base RO.

Table 3 shows the remaining IRSPs plus the PACAF totals. The optimal alternatives would increase the repair cost by $0.88M. (The repair cost is the relevant cost because changing the IRSP authorization will not affect the D200A RMS buy computation. Therefore, the only expense the Air Force will incur from changing the levels associated with the fielded IRSP kits is the repair cost.) In contrast to the optimal alternative, Alternative 5, Fixed ASL, would increase the repair cost by a smaller amount because this alternative reduced levels more than they should be reduced. The bases earned POS levels above the TWR, but the fixed ASL prevents RBL from allocating anything more than the fixed quantity, which was less than the computed offset. So the Fixed ASL option erroneously limits levels by $0.25M ($0.88M-$0.63M). Likewise, the Minimum ASL option erroneously overstates levels by $0.23M ($1.11M-$0.88M). Alternative 7, Set the IRSP Equal to the TWR—Let the POS Float, is the costliest and theoretically inferior to the other methods. Tables 5 and 6 show the AMC totals for the kits analyzed.

The optimal alternative actually reduces AMC total repair costs by $0.1M (the decreases in repair cost are larger than the repair cost increases (Table 5). Again, compared to the optimal approach, Alternative 5, Fixed ASL, would erroneously reduce repair cost by $0.07M ($0.1M - $0.032M), while the minimum-ASL method, Alternative 3, would overstate repair costs by $0.109M ($0.1M + $0.009M). Alternative 7, IRSP Equals TWR, again, is the costliest and most erroneous option.

Table 6 summarizes the totals for PACAF and AMC and provides totals for overall comparison and evaluation of the results. Note that overall, for PACAF and AMC, the optimal alternative repair costs increase by $0.78M. The minimum ASL approach incurs an excess repair cost error of $0.34M ($1.119M -$0.78M)), while the fixed ASL approach incurs an understated repair cost error of $0.18M ($0.78M-$0.598M).

Selection of an Alternative

Because of its superiority to any other method of maintaining the TWR, the Air Force should take immediate action to implement the optimal method, alternative 2. Using this alternative will ensure levels computed by both Air Force level-setting systems, RBL and WSMIS, are properly allocated and supported with D200A-computed requirement. This means establishing an interface between RBL and WSMIS. There are two options for the interface:

- Data (IRSP, TWR, and current offset) could be provided by WSMIS to RBL, which could then recompute the offset and IRSP with the latest POS levels data. RBL would then push RSP and POS levels to the bases. RBL would also provide RSP additive data to D200A to update the worldwide requirement.
- RBL could provide an automated update of POS levels to WSMIS semiannually so WSMIS could recompute and push new IRSP levels to compensate for any POS changes. WSMIS would push the levels directly to the applicable base as well as update D200A with accurate requirement data.

Until the Air Force completes the RBL and WSMIS system changes, Alternative 3, Minimum Adjusted Stock Level—Additive, best meets the AFSWPWG goal to find a way to maintain the proper RO without making a system change. Alternative 7 is not a viable option because it creates unsupportable base levels and is the most expensive option. Alternative 3 is better than Alternative 5 because Alternative 3 does not artificially constrain POS levels for cases where the POS exceeds the TWR and only marginally increases repair costs as compared to the next best option (alternative 5). Alternative 3 generates a smaller RO-levels error than the Fixed ASL option. As shown under Air Force totals for levels gained in Table 7, minimum ASLs would increase IRSP bases' RO by 833 levels but would prevent the loss, under the Fixed ASL alternative, of 1,390 levels for cases where demand would generate RBLs exceeding the TWR. In comparison to the optimal method, 607 levels should be lost, but 783 should remain untouched. Both the minimum or fixed ASL options will meet Air Force needs, but the minimum ASL option errs on the side of providing increased mission support.

	Kadena KC-135R				Kadena E-3				Osan A-10				Osan F-16			
Alternative	2	3	5*	7	2	3	5*	7	2	3	5*	7	2	3	5*	7
Levels lost	18	0	76	0	5	0	8	0	13	0	42	0	14	0	16	0
NSNs with lower RO	5	0	6	0	4	0	5	0	4	0	12	0	1	0	3	0
Levels gained	76	76	76	140	129	129	129	151	13	13	14	72	12	12	12	23
NSNs with higher RO	53	53	53	69	117	117	117	128	10	10	10	22	9	9	9	13
Repair cost ($M)	.2	.3	.2	.4	.6	.6	.5	.7	.05	.06	0	.15	.03	.06	.01	.11
	Kunsan F-16				**Kadena/Osan Common**				**PACAF Totals**							
Alternative	2	3	5*	7	2	3	5*	7	2	3	5*	7				
Levels lost	23	0	42	0	9	0	2	0	82	0	182	0				
NSNs with lower RO	8	0	12	0	9	0	2	0	31	0	37	0	*Note: The fixed ASL option reduces the RBL on some NSNs that were above the TWR.			
Levels gained	14	14	14	119	14	14	14	31	258	258	258	536				
NSNs with higher RO	10	10	10	39	11	11	11	16	210	210	210	287				
Repair cost ($M)	(.02)	.05	(.12)	0.5	.02	.04	.04	.11	.88	1.11	.63	1.97				

Table 3. PACAF Alternative Offset Comparison

	Dover C-5				Travis C-5				McGuire C-141			
Alternative	2	3	5*	7	2	3	5*	7	2	3	5*	7
Levels lost	248	0	878	0	83	0	111	0	104	0	110	0
NSNs with lower RO	66	0	90	0	35	0	46	0	40	0	42	0
Levels gained	209	209	209	1092	256	256	256	759	27	27	27	221
NSNs with higher RO	61	61	61	183	46	46	46	119	16	16	16	79
Repair cost ($M)	(.01)	.004	(.02)	.03	.000	.003	(.009)	.015	(.002)	.000	(.002)	.006
	Charleston C-17				**McChord C-141 and C-17**				**AMC Total**			
Alternative	2	3	5*	7	2	3	5*	7	2	3	5*	7
Levels lost	8	0	9	0	82	0	100	0	525	0	1,208	0
NSNs with lower RO	6	0	6	0	38	0	40	0	155	0	224	0
Levels gained	9	9	9	29	74	74	74	356	575	575	575	2,457
NSNs with higher RO	5	5	5	13	45	45	45	109	173	173	173	503
Repair cost ($M)	(.000)	.000	(.000)	.001	.113	.002	(.001)	.009	(.10)	.009	(.032)	.061
*Note: the fixed ASL option reduces the RBL on some NSNs that were above the TWR.												

Table 4. AMC Alternative Offset Comparison

	PACAF Totals				AMC Totals				Air Force Totals			
Alternative	2	3	5	7	2	3	5	7	2	3	5	7
Levels lost	82	0	182	0	525	0	1208	0	607	0	1,390	0
NSNs with lower RO	31	0	37	0	155	0	224	0	187	0	261	0
Levels gained	258	258	258	536	575	575	575	2,457	833	833	833	2,993
NSNs with higher RO	210	210	210	287	173	173	173	503	383	383	383	790
Repair cost ($M)	.88	1.11	.63	1.97	(.10)	.009	(.032)	.061	.78	1.119	.598	1.909

Table 5. PACAF, AMC, and Air Force Totals

To implement the minimum ASL option, IRSP bases should load an ASL detail equal to the amount of the IRSP offset. The bases should load an ASL for one plus the TWR minus the IRSP authorized quantity for all cases where the TWR minus the IRSP is positive. If the TWR equals the IRSP (that is, TWR minus IRSP is zero), then no ASL is needed. For example, if the TWR equals two and the IRSP authorized quantity is zero, the ASL would be three. (Recall the offset is the POS level minus one.) If the TWR equals two and the IRSP also equals two, no ASL is needed.

One exception is made to the rule: when there is no consumption data for that NSN at the IRSP base (the RBL level would be zero), the ASL should be set so the IRSP plus the offset equals the TWR (not the TWR plus one). This is because all POS should be on hand at the beginning of a contingency if there is no demand. For example, if the TWR equals two, the IRSP is one, and the base daily demand rate (DDR) is zero (therefore, the RBL is zero), the ASL should be set at one.

Summary for Determining the Minimum ASL Quantity

If the TWR = IRSP, then no ASL is needed
If the TWR > IRSP, and
a. If the DDR > 0, set the ASL quantity to 1 + (TWR – IRSP)
b. If the DDR = 0, set the ASL quantity to TWR – IRSP

Implementation Actions

In August 2000, AFSWPWG implemented the minimum ASL options. IRSP bases loaded ASLs for the currently fielded kits rather than waiting for the new kits. The ASLs were loaded with an Air Force level directed by code *D*, so that RBL will accept the base-generated XE4 transactions containing the ASL data (for transmission to the D035E database) directly from the base and load the ASL without requiring item-manager-specialist file maintenance.

The Air Staff appointed the Requirements Team to oversee the process to ensure the ASLs are properly loaded at the base and in the RBL database (D035E). The Requirements Team coordinated with the MAJCOMs and bases and ensured ASLs loaded at the base were accurately reflected in D035E. When the new IRSP is fielded, the team will ensure the old ASLs are deleted and new ASLs are properly loaded. The Requirements Team will periodically reconcile the base-provided list of ASLs with the data loaded in D035E. AMC developed a surge program to automate the creation of ASL load images (1F3).

Related Issue

The offset amount exceeded the TWR in many cases. Also, eight of the IRSPs (Osan A-10 and F-16, Kunsan two F-16s, Kadena KC-135R and E-3, and McChord C-141 and C-17) are colocated and share common components. This complicates the process of determining the proper offset amount. The offset is the POS level minus one, yet for a shared item (an item in more than one IRSP at the same base), the entire POS level cannot be applied to both IRSPs. Since the kit reviews are at different times for different weapon systems and there is no systemic way to group kits or offset amounts by base, it is unclear whether the offset amounts are being properly determined and loaded into WSMIS. The kit requirements are computed by kit, not by base, yet the most accurate way of applying offsets is by base for common items.

Only 50 to 60 common items in the kits were examined, so a systemic solution may not be cost-effective. But clear procedures should be provided to determine the proper offset amount for items at a base common to two or more IRSPs. The offset should be determined *for the base* as the POS level minus one. Then the IRSPs should share the offset quantity. For example, a base with a POS level of four has two IRSPs, one with a TWR of two and one with a TWR of four. The total offset is three (four minus one). The first IRSP should have an offset of one, and the second IRSP should have the remaining two as an offset.

Conclusion and Recommendations

Bases with IRSP have ROs less than their TWR. PACAF has 210 NSNs with ROs less than the base TWR. AMC has 173 such cases. Offsetting wartime levels with POS expected to be on hand for wartime activity at bases with IRSPs is theoretically sound and saves the Air Force nearly $55M of gross requirement. The optimal alternative (that is, best long-term solution) is interfacing WSMIS and the D035E RBL system. Either one of two methods will work:

- Vary the IRSP level depending on the most current RBL for the using base.
- WSMIS provides RSP data to RBL, and RBL then pushes RSP levels in addition to RBL-computed POS levels (this solution requires system changes).

As a short-term approach, the minimum ASL option will ensure base levels at least equal their TWR and will not constrain base ROs for bases that are allocated peacetime levels above their TWR. This option has minimal impact on the requirements system, increasing repair costs by an estimated $0.34M over the optimal method, and does not require any systems changes.

The fixed ASL option will ensure base levels are at least equal to their TWR and actually reduces repair costs by almost $0.18M over the optimal method, but it will reduce POS levels by 1,390, more than twice as many as the optimal method, more than is prudent. Setting the IRSP level equal to the TWR (in essence treating the IRSPs like mobile readiness spares packages) is the costliest option. It increases the Air Force repair requirement by $1.13M over the $0.78M repair cost for the optimal method.

Eight of the current IRSPs have parts common to other colocated IRSPs and, therefore, may have improper offset calculations.

The AFWSPWG should approve and implement the Seamless Supply Working Group initiative that makes system changes to implement the optimal method. In the interim, the AFWSPWG should approve IRSP bases to load minimum ASLs at their applicable offset quantities, equal to what the POS level should be to ensure that the base RO meets its TWR; specifically, one plus the TWR minus the IRSP authorized quantity (1 + TWR - IRSP) for all cases where the TWR minus the IRSP quantity is positive. The only exception to this rule would be cases where the base's DDR is zero; then the ASL should be set so the ASL plus the IRSP equals the TWR. The AFWSPWG should develop and implement a surge program to compute and format ASL loads for items where the TWR does not equal the IRSP authorized quantity. It should assign the Air Force Requirements Team to oversee the process to update ASLs for IRSP bases and develop and document clear procedures for determining peacetime offsets for items common to two or more IRSPs at the same base.

Captain Spencer is a logistics career-broadening officer at the Oklahoma Air Logistics Center, Tinker AFB, Oklahoma. At the time of writing of this article, he was Chief, Requirements Policy Branch, Supply Division, Air Force Logistics Management Agency, Maxwell AFB, Gunter Annex, Alabama.

AFMC Studies and Analysis Program

Mike Niklas
Air Force Materiel Command

The Management Sciences Division (AFMC/XPS) provides a source of operations research skills for Headquarters AFMC. Although a part of the Directorate of Plans and Programs, the division often performs studies and analyses for clients outside the directorate. Most of the analysts have advanced degrees in technical areas such as operations research, mathematics, engineering, and management sciences.

We conduct and sponsor studies and research in a variety of key areas. Our goal is to provide analytic solutions for improved business practices. One way this is accomplished is by quantifying the relationships between alternative resources and the resultant support (aircraft availability or missions accomplished) so AFMC can prioritize and justify its investment in those resources. We also pursue a few internally developed projects that have significant potential for providing insights into these relationships.

In 2000, we devoted a major portion of our efforts toward implementing and improving methods for managing materiel spares and expanded our scope of responsibility to other mission areas where we could apply analytic tools and provide decision support products. Generally, our tools and products helped the mission areas determine requirements, allocate resources, execute support actions, and assess impact. Details and points of contact for topics mentioned in the following summary are available in our 2000 annual report at https://www.afmc-mil.wpafb.af.mil/HQ-AFMC/XP/SAO. Printed or electronic copies of the XPS Annual Report can be obtained from Mike Niklas (937-257-7408 or mike.niklas@wpafb.af.mil).

The Management Sciences Division continues to support the Execution and Prioritization of Repair Support System (EXPRESS) by increasing visibility of awaiting-parts delays at depots, addressing interchangeability issues, controlling inflation of distribution priorities, reengineering the scenario subsystem, and developing tools to facilitate trend analysis and performance measurement. We also examined the value of using requisition objective holes versus back orders as objectives in the optimization model. EXPRESS is operational at all Air Force depots where it supports their most important workload.

During the spring and summer of 2000, XPS provided analytic support to the C-5 Tiger Team, which traveled to all the C-5 main operating bases, all air logistics centers (ALC), and the Defense Logistic Agency (DLA) looking for best business practices and ways to improve the mission capability of this aging weapon system. Management Sciences' role on this team was to quantify the impact of numerous issues that were uncovered. EXPRESS fell victim to a great deal of criticism throughout this effort, most of which was anecdotal and not supported by data. Another concern was whether interchangeability and substitutability issues were causing mission capability (MICAP) problems. The final area of analysis was demand forecasting. There was a strong opinion that the 8 quarters (2 years) of historical data the Air Force uses to forecast future demands are inadequate to capture the failures that occur in a cycle longer than 2 years. While there are some philosophical arguments against this concern, we compared the current 2-year, moving-average forecast to a 5-year moving average to see if there would be any benefit to capturing more data. The analysis showed that simply using more historical data does not provide a better demand forecast than the current process. However, this does not mean there is no room for improvement in the current forecast methodology.

We helped the Scientist and Engineer Career Program (SECP) Executive Panel address declining retention rates within the Air Force over the last decade. Management Sciences cochaired the Motivations Working Group (one of four working groups under the Goal 2 Panel of the SECP) and considered several options for gathering data. The group determined that focus groups were the best method for gaining the needed insight into the attitudes of both military and civilian scientists and engineers about their careers in the Air Force. The purpose was to obtain causal data to gain an understanding of the underlying reasons for the declining retention rates. Those causal reasons were then provided to other working groups that identified measures for implementation that could positively change the trend.

Most of our efforts for Secondary Item Requirements System (D200A) support focused on the significance of various funding-induced limits. Mission area negotiations for limited budgetary resources prompted us to develop a tool to bring objectivity to AFMC Command Prioritization of Funding Alternatives. In a review of Supply Management Activity Group (SMAG) cost recovery and rate and price validation, the repair of Materiel Support Division items not sold was found to be a major cause of cash loss. We looked into the reasons the items did not sell and other clues to understanding the SMAG sales disconnect. Additionally, we worked readiness-based leveling issues concerning problem parts, adjusted stock levels, high MICAPs, and model maintenance.

We evaluated proposed depot stockage policies and worked on a requirements model with DLA to improve Air Force consumable-item support to depot maintenance.

Last year, we prescribed a number of improvements to the Weapon System Support Program. This year, we followed up on the approved recommendations by defining specific implementation tasks to enable development of the new system.

(Continued on page 41)

AFIT Graduate Students Tackle Complex Logistics Problems

William A. Cunningham III, PhD
Air Force Institute of Technology

The 18-month Logistics Management master's degree program at the Graduate School of Engineering and Management, Air Force Institute of Technology, prepares logisticians to apply quantitative and analytic methods to assist high-level decision makers in the management of logistics, transportation, maintenance, and inventory systems. Seventeen officers are scheduled to graduate in March 2002—8 US Air Force, 1 US Army, 1 from Argentina, 2 from Brazil, 2 from Korea, 1 from Taiwan, and 2 from Turkey.

The heart of the program is the 9-month research effort on a complex military logistics problem, culminating in a master's thesis. Thesis topics and sponsors are listed below. If you have questions or suggestions, please call the faculty advisor.

- Captain Roberto C. Abreu (Brazil), "P-METRIC—An Approach to Assessing and Accounting for the Effects of the Variability on Time Parameters for Multi-Item, Multi-Echelon, Multi-Indenture Reparable Inventory Systems," Advisor: Major Stephen M. Swartz (937-255-6565, x4285, DSN 785), Sponsor: Brazilian Air Force
- Captain Todd S. Bertulis (US Army), "Interim Brigade Combat Team Munitions Distribution Study," Advisor: Lieutenant Colonel J. O. Miller (937-255-6565, x4336, DSN 785), Sponsor: US Army Combined Arms Support Command
- Captain Brian J. Botkin, "An Analysis of Alternate Fuel Delivery Methods for the Central Europe Pipeline System," Advisor: Colonel William P. Nanry (937-255-6565, x4339, DSN 785), Sponsor: Defense Energy Support Center
- Lieutenant Colonel Hugo Gustavo Di Risio (Argentina), "Method for Selecting the Right Air Force Supplier," Advisor: Lieutenant Colonel Stephan P. Brady (937-255-6565, x4284, DSN 785), Sponsor: Argentinean Air Force
- Captain Heinz H. Huester, "Analysis of Supply and Transportation Merger," Advisor: Dr William A. Cunningham III (937-255-6565, x4283, DSN 785), Sponsor: Air Force Materiel Command, Transportation Division
- First Lieutenant Ahmet Ilbas (Turkey), "Offsets in International Weapon Acquisitions: The Turkish Experience," Advisor: Major Stephen M. Swartz (937-255-6565, x4285, DSN 785), Sponsor: Turkish Air Force
- First Lieutenant Andrew C. Jones, "Analysis of Elmendorf AFB Throughput Capability Using the Airfield Simulation Tool," Advisor: Dr William A. Cunningham III (937-255-6565, x4283, DSN 785), Sponsor: US Transportation Command
- Captain Jung Jin Kim (Korea), "Comparative Analysis of Leasing Versus Buying General Purpose Vehicles in Republic of Korea Air Force," Advisor: Dr William A. Cunningham III (937-255-6565, x4283, DSN 785), Sponsor: Korean Air Force
- Captain Jae Yung Koo (Korea), "Supply Chain Management: A Case Study Approach," Advisor: Lieutenant Colonel Stephan P. Brady (937-255-6565, x4284, DSN 785), Sponsor: None
- First Lieutenant Kubilay Kosucu (Turkey), "Estimating the Operating and Support Cost Difference Between the Turkish Air Force C-130E/B and the US Air Force C-130J," Advisor: Major Stephen M. Swartz (937-255-6565, x4285, DSN 785), Sponsor: Turkish Air Force
- First Lieutenant Daniel D. Mattioda, "Use of Critical Chain Scheduling to Reduce Aircraft Downtime During Scheduled Maintenance: A Case Study of the Special Operations C-130 Aircraft Isochronal Inspection Process," Advisor: Major Stephen M. Swartz (937-255-6565, x4285, DSN 785), Sponsor: Air Force Special Operations Command, Logistics Directorate
- Captain Samir Mustafa (Brazil), "Feasibility of Using the Brazilian Air Force Integrated Logistics System by the Logistics and Mobilization Agency as a Base Logistic System for Brazilian Armed Forces," Advisor: Major Stephen M. Swartz (937-255-6565, x4285, DSN 785), Sponsor: Brazilian Air Force
- First Lieutenant Robert E. Overstreet, "A Quantitative Analysis of the Resolution Alternatives to Diminishing Manufacturing Sources and Material Shortages," Advisor: Major Stephen M. Swartz (937-255-6565, x4285, DSN 785), Sponsor: Defense Supply Center
- Captain Douglas C. Patton, "Developing and Validating an Upward Feedback Instrument for Mid-Level Supervisors," Advisor: Major Paul W. Thurston (937-255-7777, x3276, DSN 785), Sponsor: Air Force Security Assistance Center, Aeronautical Systems Center, and Air Force Materiel Command
- Captain Craig A. Punches, "A Mathematical Model to Aid Selection of an Optimal Force Mix: Balancing Resource Suitability and Logistics Supportability," Advisor: Major Stephen M. Swartz (937-255-6565, x4285, DSN 785), Sponsor: Defense Advanced Research Projects Agency, Advanced Logistics Project
- Captain Shenn-Rong Shyong (Taiwan), "Advanced Planning and Scheduling in USAF Depot-Level Maintenance," Advisor: Lieutenant Colonel J. O. Miller (937-255-6565, x4336, DSN 785), Sponsor: Air Force Materiel Command, Logistics Directorate
- Captain Joseph B. Skipper, "An Optimization of the Hub-and-Spoke Distribution Network in United States European Command," Advisor: Dr William A. Cunningham III (937-255-6565, x4283, DSN 785), Sponsor: Theater Distribution Management Cell

AFIT is looking for new logistics-related thesis topics for the class that entered in September 2001. If you would like to discuss potential research opportunities, please call Dr William A. Cunningham III (937-255-6565, x4283, DSN 785) or e-mail him at william.cunningham@afit.edu.

Murphy's Law

Lieutenant Colonel Logan "Jay" Bennett, USAF, Retired, with editorial assistance from Lieutenant Colonel David W. George, USAF, Retired

Colonel Crawford O. Murphy was my boss for 1 very remarkable year in the late 1970s. I was in a very comfortable assignment at the Military Personnel Center, Randolph AFB, Texas, but chose to go to Osan AB, Korea, for my second remote assignment in 15 years. About a month before departing, I received my first correspondence from the unit's deputy commander for maintenance (DCM), Colonel Murphy. It was a handwritten note stating, "Don't bring your golf clubs; we don't have time for it here." I'd heard all sorts of stories about this intrepid character (most recently from a friend, Major Luke Gill, who had arrived at Osan AB months earlier), so my anxiety was heightened with this caustic note. In the next 12 months, I was to receive many of these notes.

My assignment, on paper, was to command the component repair squadron (CRS). However, when I arrived, the departure of several field grade officers meant the maintenance control officer, CRS commander, aircraft generation squadron (AGS) commander, and quality control (QC) jobs were all up for grabs. Murphy wanted time to evaluate the possible replacements before selecting them. He insisted that departing incumbents remain in place until the very end of the month they were eligible to return from overseas. (All incoming field grade officers arrived at the beginning of the month. A year later, they left Osan at the end of the month, making this nearly a 13-month tour of duty, a Murphy policy.)

Colonel Murphy interviewed all senior noncommissioned officers (NCO) and officers one-on-one within days of their arrival. This interview was strictly a one-way conversation. Here's the nature of my interview, as I've kept my notes over the years and used them myself.

- Be happy and aggressive.
- Know the -6.
- The squadron maintenance supervisor runs maintenance.
- Production belongs to the senior NCOs, not the officers.
- Identify weak people and press them to become stronger.
- Don't accept anything short of perfection.
- No battles, period.
- Quality assurance (QA) reports are to be answered with what we're doing to correct the problem.
- Know at what level decisions should be made and hold those people responsible.

In about 2 weeks, Murphy made his decision on assignments, and I was extremely fortunate to be selected to command the AGS, replacing the extremely popular and very competent Major Dick Rose.

In those days, Osan (51^{st} Composite Wing) had 24 F-4Es, 16 OV-10s, and a full-time detachment of 6 RF-4Cs. The maintenance organization was an early production-oriented maintenance organization (POMO), with a DCM—Colonel Murphy, also known as *Alpha One*. While the tour of duty was nearly 13 months for most of us, certain key staff members served longer tours (Murphy served for 3 years).

My memory is very clear about those events 22 years ago, serving as AGS commander under Alpha One, and I would like to share some of those experiences with you.

Permit me to describe a standard day. It always began at 0430 (except for Sunday) with a phone call to my quarters. I was usually in the shower at that time and kept a close ear for the ring. It was Colonel Murphy. "Good morning, are you the commander of the *Animal Gathering Society* (sometimes it was the *All Girl Squadron*)?" This was followed by a long pause. "Major, why aren't your crew chiefs getting their paychecks on time?" Or, "Why do your crew chiefs need haircuts?" Or, "When are you going to insist on clean forms on your airplanes?" Then, before I could answer, he would hang up. After a few of these calls, I became very annoyed, with him and with my inability to anticipate his daily questions. It soon became apparent that Alpha One cruised the flight line every morning from 0300 on, searching out *his people*, my crew chiefs. After several weeks of this, I eventually got used to it and followed up during the day, unless it was an airplane problem, which I investigated before I left my quarters in the morning.

I always stopped by job control before starting my rounds. Murphy's job control was unique, as were his expectations. Every decision that could be moved from job control to the flight line was, letting the AGS expediter work the problem through the specialist supervisors on the line and work out a course of action. Job control was to let that course of action stand unless they could prove it impacted future schedules—or other priorities to the on-scene bosses—to prepare aircraft to fly. Job control should keep reminding the flight line of considerations, and they should obtain the help on-scene bosses needed. Colonel Murphy considered the AGS expediter the orchestrator of the ongoing maintenance effort. He spent lots of time needling the specialist dispatchers for failing to keep the work force occupied when there was something productive they could be doing, such as dispatching avionics specialists to clear delayed discrepancies. He never let the shop chiefs forget they were the ones who should

be bugging job control for an airframe or to do what needed to be done.

After establishing how the schedule was being met for the day, I usually visited each shelter that housed an aircraft on the day's flying schedule. Over time, you could tell just by looking at the activity (or listening to the radio) whether the bird was coming together or not. It was especially nice to have fewer than 50 airplanes—knowing tail numbers, locations, names of the crew chiefs, and the aircrafts' history wasn't difficult.

Colonel Murphy's reputation, integrity, and work ethic centered on scheduling. With 27 F-4Es authorized and 24 or so on station (2 or 3 were often at programmed depot maintenance), his ironclad policy was to keep half of them on the ground for scheduled, unscheduled, and delayed maintenance; time compliance technical orders; washes; paint; weapons load training; and so forth. He forbade any tail number *swapping*, with the policy concurrence of the deputy commander for operations and the wing commander. In short, if aircraft 421 was scheduled to fly on Monday, Tuesday, and Thursday, it damn well flew on those days. No one substituted one airplane for another, or they would have been fired. Case closed. If the wing commander took aircraft 551 to Kunsan for a conference on Monday and returned that evening with it out of commission, it was not substituted if it wasn't able to fly as scheduled on Tuesday. That's what spares were for. On a typical day, using 11 jets, the schedule called for 9 + 3; that is, 8 + 3 spares on the first go. The turn was a diminishing rate, 8 + 4, then 7 + 5, and so on. I recall, quite early one morning when driving down B-ramp, seeing two crew chiefs scuffling in front of a shelter. I broke it up and asked why they were fighting. Colonel Murphy had been by that morning and said the crew chief of the aircraft flying the most sorties that day would get something special from him (probably a six-pack if memory serves me.) The scuffle broke out because one crew chief's airplane was a spare that day and he was being teased by the other guy because the spare would never be flown and was thus ineligible for the Alpha One *special*.

Combat turnarounds occurred almost every day. A special location was set up where returning jets were *combat turned*, engines running, weapons loading, refueling (engines were shut down), and overall servicing, including the through-flight inspection. We often *turned* aircraft in less than 30 minutes. Given the scheduling scenario of a diminishing number of follow-on sorties with each turn, there were always plenty of airplanes available, mainly because of the discipline Murphy had established for scheduled maintenance on nonfly days. That was the key to his extraordinary success. (From July 1978 to July 1979, the wing had an astonishing 1.02 sortie rate for the F-4E.) I cannot emphasize enough the discipline that made this system work. No one changed the weekly schedule, where tail number assignments were published. It was common at the end of the flying day to have airplanes fully mission capable and no pilots to fly them. There were no exceptions to the *no change* policy unless we had an operational readiness evaluation or operational readiness inspection (ORI), and obviously, the wing then had to generate *all* aircraft.

Perhaps now would be an appropriate time to share an event that occurred on 9 November 1978 during an ORI. At about 1700, following an especially tough flying day (one F-4 needed an engine change, and one had a serious fuel leak), the Pacific Air Forces (PACAF) ORI team landed after holding on final for an F-4 to be removed from the barrier. The senior maintenance inspector, Lieutenant Colonel Harry Blue, went directly to job control where the commanders and maintenance supervisors were assembled. Harry walked in, checked the status, got the *brief* from the maintenance control officer, and commented to me when he walked out, "You'll never make it." We had 24 F4-Es and about 15 OV-10s, and no one knew how many RF-4Cs Kadena would send us. Of the F-4s, five were in very serious shape, including one in phase and one in phase prep, besides the two with major problems mentioned above. We needed to generate all 24 F-4s in 12 hours, or by 0500 the next morning, to get the top rating. We returned to our squadrons, established the shifts, and subconsciously fretted over how in the *Sam Hill* we would get it done. Murphy always went to the officers club for dinner at about 1800. Always. There was a special maintenance table at the club in those days that sat about a dozen people. The head seat was Alpha One's. No one else sat in that seat, unless it was a tourist (upon which Murphy would exit the club and go to his quarters). That infamous night, Murphy went to the club as usual, ate alone (the rest of us were sweating bricks on the flight line), and then went to his quarters on the hill. All night, we watched the activity on the line, and one by one, the jets came together. Murphy showed up at about 0400, just in time to watch the last of the engine changes—the engine run and the preflight completed about 5 minutes before the 12-hour generation expired. All 24 F-4s, OV-10s, and RF-4Cs were in-commission and preflighted. The ORI report read in part:

> The professionalism displayed throughout the maintenance complex was the best observed in PACAF . . . . "Excellent" rating for the DCM complex . . . and, "highly commendable" on the unit's miraculous recovery from severely degraded maintenance following an especially tough flying period.

Months later, during a rare post-dinner exchange with Alpha One, I asked him about that evening. "Colonel, during the most important period of time during our assignment here at Osan, you were in your quarters. I don't understand." His comment was enlightening, "Jay, I spent months preparing you and the other members of my team to go to war. My goal was to put you all in a position to lead the effort, and you did. I wasn't needed, and my presence would have had a negative impact on your efforts." That was classic Crawford Murphy.

Aside from the normal, day-to-day activities of a flying unit, our role as commanders was to deal with our people and their problems, with an unrelenting eye (and ear) on generating airplanes. Not that we had to have the job control net in our office (we didn't), but our maintenance supervisors were always keeping us informed. Murphy made it very clear to all of us that *production* meant senior NCOs and *management* meant officers. The real power belonged to the E-6/E-7 line chiefs and our superintendents. The officers provided the wherewithal for them to do their job.

Which brings me to the subject of meetings under Alpha One. He believed big meetings with lots of people invited decisions to be made at too high a level. He felt that hardly ever in a meeting atmosphere does the DCM make a decision that couldn't be made better by someone below him. He also said that because the boss in those circumstances seldom had enough information to make the right decision the decisions made were "usually unmade by sundown." He believed the DCM should do only those things

that only he could do. For example, he thought it was most absurd to have people call him to get approval for cannibalizations. Most of the decisions traditionally reserved for DCMs were, in his view, inappropriate because they were decisions dealing with the minutiae of executing plans, programs, or schedules. Murphy decided, with advice, how many sorties to fly in a period and what patterns to use in scheduling. He would set the policy on what types of things to cann or what types of missions to support. That would allow others to make the right decisions on each occasion. So what about his meetings? There was only one, the *Seventeen-ten* (1710). The meeting was called by the noncommissioned officer in charge (NCOIC), Deficiency Analysis (an E-7) whenever there was a deviation from the day's flying schedule (air abort, ground abort, maintenance nondelivery). It didn't matter if it was triggered by a deviation at 1700 that day or 0730, and if there wasn't a deviation, there was no 1710. Each commander; maintenance supervisor; complex superintendent (a chief); QC officer; maintenance control officer; job control officer; and NCOIC, Deficiency Analysis showed up in Murphy's small office. There weren't enough seats, so one person stood (usually Captain "Bubba" Parker, my maintenance supervisor). The meeting began promptly at 1710. Murphy wanted the entire wing complex, most of whom had gone to their quarters by then, to know that the DCM complex was on *point*. The NCOIC, Deficiency Analysis opened the meeting by saying something like, "Aircraft 330 had a ground abort for a leaking brake," upon which Murphy would look right at me with hawklike eyes and ask why. Bubba would tell him the brakes had been changed in phase the day before, and Murphy would look at Luke and ask why. Captain Steve Smitherman, the emergency mission support maintenance supervisor, would say, "Sir, the brake stack was installed backwards and Airman so-and-so was unsupervised, and Staff Sergeant Smith or Jones failed to do an IPI." Murphy would then look to the QC manager (Major Rich Romer) and ask why QC didn't catch it. Sometimes this dialog would last half an hour on each deviation until he was satisfied the root causes were discovered. Days with more than one deviation often had the 1710 go way past 1830. After deviations were discussed, every repeat and recurring writeup written since the last 1710 meeting was discussed. Sometimes, we hashed over scores of these with the same dissecting inquiry used on the deviations. At least, we had time to prepare for these. I recall never going more than a couple of days without a 1710 that year with mixed emotions, because if we had, it would have allowed a lot of repeat or recurring writeups to pile up.

After the 1710, most of us returned to our offices to wrap up the day and make sure the swing shift course was set. Then off to dinner at the officers club, where we would probably find Alpha One finishing his meal and others in various stages of dinner. The dinner period was enjoyable—not a lot of shoptalk—rather, poking fun at each other and once in awhile taking a fun shot at Colonel Murphy.

Once during our tour, each officer was invited to Murphy's quarters for homemade soup. That was a very special occasion, and surely, all of us have special memories of that event. The setting was a little awkward given the circumstances—a bachelor colonel's quarters—with classical music. The soup was superb. The evening lasted about 90 minutes, and then it was time to go. No shoptalk, just listening to him read some favorite poems or inquiries about our family and life.

Saturdays were like every other day for the most part, occasionally with only half a day flying. We never flew on Sunday. I used Sundays to spend quiet time with each airplane, without any company, to review the forms and evaluate the overall condition of the airplane. Dirty airplanes were not acceptable, and had Murphy found one to be unacceptable, I would catch hell. That included faded paint or greasy fingerprints on access panels. The crew chiefs knew it, too, as they were pampered by Alpha One almost to the point of fraternization. He knew them all by name, often their backgrounds and individual personalities. I recall the image of a crew chief leaning in the open window of Murphy's pickup truck at 0500 or 1000 or 1430, joking with their big boss. He loved those crew chiefs. He often had lunch with them in the flight-line cafeteria, a facility that he insisted on having near the troops.

I saw Colonel Murphy cry one time, and I hope he forgives me for bringing it up, but it shows the compassionate side of this special person. One of his favorite crew chiefs was a staff sergeant who was on his third year at Osan. He was married to a Korean national and was also one of the most respected mechanics in the complex. This sergeant was indicted for black marketing activities (he sold a washing machine to a Korean). When Colonel Murphy learned of this, he cried like a baby. He was devastated. Murphy spoke on his behalf at the court martial in emotionally muted tones you could barely hear in the courtroom.

There are, of course, far too many memories to capture in this narrative about Alpha One. Each one of us was pushed to our full potential, and in my case, I carried his intensity and focus on to greater challenges in subsequent assignments. It became natural in the years following Osan, when faced with problems and decisions, to find the clear and correct course of action using the foundation provided by him. He was outspoken and light-years ahead of his time, but his focus was always the same. In my later active duty and Boeing years, some of my decisions were challenged and criticized, often by government agencies with a different agenda, but my bottom line was always a clear conscience with the knowledge that I had done the right thing. I owe that to Crawford O. Murphy.

Some of us stayed in touch with our old boss over the years. He retired in the early 1980s and returned to his birthplace and home in Cambridge, Maryland. There he was affectionately known as Neal. I visited him twice and found him to be very happy and comfortable. He remained a bit curt and always the disciplinarian but very modest and full of life. He passed away in the early 1990s.

Crawford Murphy should have been promoted again. He made colonel in less than 15 years, as a nonrated maintenance officer. His downside, I am told, was his impatience with higher headquarters and the reorganization of aircraft maintenance that was occurring in the Air Force. His attitude on that was unacceptable to his superiors, but he, nevertheless, voiced his objections at every opportunity. His messages were infamous. One I will never forget was known as the *Shah of Iran* message. It started out in a message to Third Air Force and PACAF. "I feel quite certain that the Shah of Iran thought the only obstacles to his program were some older supervisors who were resisting change." He then went on to outline two major logistics initiatives (POMO and centralized intermediate repair facility [CIRF]) in PACAF that he felt were detrimental to "flying plenty of safe and effective sorties," his motto. He believed the idea of

a self-sufficient aircraft maintenance unit (AMU), the heart of POMO, was an appealing idea. However, he also felt it took far more fully qualified and experienced technicians than we could afford, working in a more stable environment than we could provide. Additionally, he felt that the specialists, under POMO, were fragmented and that led to instability. Constantly moving and borrowing specialists between shops and other AMUs turned out to be an unsupervised nightmare and led to poor quality work. He also believed the quality of troubleshooting was reduced under POMO because complete malfunction histories were not readily available to supervisors. Finally, he believed qualified supervision was seriously reduced, primarily because the system would not provide the smaller work centers with the higher NCO grades previously authorized in the larger organizations.

Crawford Murphy worked with CIRF for 3 years. He didn't believe it enhanced our combat capability in Korea; he felt CIRF degraded it. Remember, he was managing F-4 and OV-10 aircraft with considerable intermediate-level maintenance requirements. The loss of a reparable asset out of the base-level maintenance system was unacceptable. He also felt that airlift, absolutely critical to a functioning CIRF, made the whole process extremely vulnerable in wartime. The loss of the base-level pipeline, from shop to flight line to supply, was simply unacceptable. His arguments continued with challenges to the economics of the system, the increased damages to avionics line-replaceable units, and loss of the capability to rapidly fix bad boxes during wartime.

In his end-of-tour report, he credited the "unparalleled cooperation of the aircrews and their bosses . . . who willingly did the mission in a fashion that provided us the best chance of success regardless of their personal druthers."

Some Murphyisms:[1]

- Commanders are supposed to command—maintenance control officers are supposed to stay in maintenance control and not bother anybody.
- Maintenance control officers are not supposed to be out on the flight line—that is squadron business, not maintenance control business.
- First of all, it's [maintenance] going to have one boss—me. I will not ask and do not expect either my assistant, my maintenance control officer, or my squadron commanders to set maintenance policy. I want one clear source of policy—me. However, I want my commanders to command. I do not want my staff to interfere in that command.
- The single most important thing controllable at wing level that will advance the sortie-production goal is to follow the weekly flying schedule. Once it has been decided which aircraft will fly on which days, do not change it. If you think just a few changes will be acceptable, you are wrong. When your people realize they can count on the schedule about as well as a sunrise, you can be sure they will fight to fly that schedule.
- I hear officers shy away from field assignments because the risks are high, exposure low, and the work hard and less forgiving. Base-level jobs were, in my opinion, the most difficult—and for me the most rewarding—and they were the ones where the rubber meets the road and the flying and fighting are done.
- Probably the most frustrating job is being my maintenance control officer. Most maintenance control officers think they control maintenance. I don't want that. I want him to coordinate all operations staff and supply matters and coordinate maintenance schedules. The NCOs on the flight line do a marvelous job controlling maintenance and do not need lots of direction. There is no need for directions from job control, just information and outside support.
- I expect being my assistant DCM must be a frustrating affair. I always instruct my assistant to not give any instructions or directions to maintenance people about the job of maintaining aircraft. I never ask him to catch the overflow and do things that I don't have time to do. The assistant is responsible for civil engineering programming, manpower changes, communications, budget, programs and plans, and training. He is in charge of ORI procedures and maintenance manning in the command post during exercises and preparing nominations for unit and individual awards. Two areas that make me the most money are his actions in manpower and civil engineering matters. No one is usually working those areas daily to get results; he does and gets results.
- I think all squadron commanders who work for me would agree there really are only a few things that I insist be done my way. They have more decision-making power than any maintenance squadron commander I know. One of my favorite answers to a question is, "I don't plan to answer that—you do what you want to do." If I think they made a dumb decision, I tell them, but I don't pull the decision up to my desk when they make a dumb one.
- I ask commanders to tell me why we have holes in the schedule and what they are doing to prevent it from happening again. It is useless to discuss preventive action unless you know who did what wrong. Only then can you find out why it is done wrong, identify the cause, and develop a good corrective action.
- Insist that your people be aggressive supervisors. Ask them to do the maximum, not the minimum acceptable. If they are the type person who will do only those things that, if left undone, you could prove they should have done, then they are meeting the standard. To be outstanding, they must do the things their bosses wouldn't even know they had the opportunity to do until they saw it done.
- I warn incoming supervisors they have two tasks anytime they receive a QA report: one, identify deficiencies and, two, do not debate the validity of the report. Once the report is written, the owner of the deficiency needs to fix the problem and prevent it from recurring as best he can. Reporting deficiencies is not a happy business. I want a ranking officer in QA. Only my assistant and I outrank him. Each morning before 0700, I have my QA officer bring me the results of the on-aircraft inspections of the last 24 hours. I want to be in a position to mention success and failure to those responsible as I visit them during the day. I see all QA reports when they have been completed to show cause and corrective action and preventive action. Most failures of QC control inspections are directly attributable to first-line supervisors; either they did not teach the failed technician how to do the job, or they did not insist that the technician do the job he was trained and directed to do.

Notes

1. Taken in part from "Compendium of Things" authored by Colonel Murphy, and sent to me in 1979.

Colonel Bennett retired from the Air Force in 1986 as chief, Aircraft Division, Ogden Air Logistics Center. He spent his entire career as a maintenance officer commanding four aircraft maintenance squadrons and held staff positions in numbered air forces, major commands, and the Air Staff between field assignments. He retired in 1999 from the Boeing Commercial Airplane Company where he held senior management QA positions in the 737/757 factory, Delivery Center and Flight Test.

("Forecasting Readiness" continued from page 1)

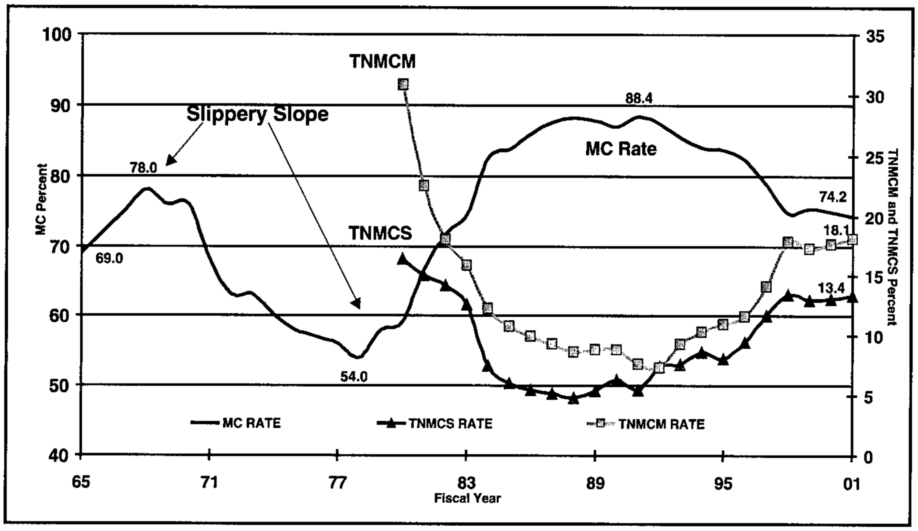

Figure 1. MC Rates for Fighter Aircraft (MC, TNMCM, and TNMCS Rate Changes, 1965-2001)

consider other factors that could impact MC rates. Specifically, the FAMMAS model does not incorporate any logistics or operations-related factors into its prediction computations of MC rates, other than historical TNMCM and TNMCS data that act as adjustment factors in the model. Recent studies have identified many factors related to MC rates: maintenance manning and experience, retention, break and fix rates, operations tempo (OPSTEMPO), spare parts issues, and reliability and maintainability (R&M) of aircraft systems, among others.[5] A review of aircraft readiness literature of the 1970s, 1980s, and 1990s indicates that most of these factors can be grouped into one of the following categories: aircraft R&M, aircraft operations, logistics operations, personnel, environment, and funding (Table 1).

Unfortunately, there have been few attempts to include these different factors in the construction of a mathematical model that explains and forecasts MC rates. While FAMMAS is an effective tool for predicting MC rates, it does not adequately consider other significant factors besides funding. Furthermore, it does not identify potential cause-and-effect relationships that might be manipulated to affect future MC rates; it just projects trends into the future.

This research attempts to satisfy these deficiencies in forecasting capability. While time-series models like FAMMAS produce accurate forecasts by projecting trends, that is all they provide. Time-series forecasts are based on data trends, not explanatory data. Explanatory forecasts may reveal potential cause-and-effect relationships that might be manipulated to have an effect on future forecasts. Explanatory forecasting techniques, such as regression, can be used with greater success than time-series methods for policy and decision making.[6] With fewer resources available to the Air Force and continued emphasis by senior leadership to use resources more efficiently, the Air Force cannot afford to use its resources indiscriminately with little knowledge about how their use will impact mission needs and goals. The Air Force needs to develop more precise analytical tools in making resource allocation decisions. These tools should assist in determining what results might arise from the allocation and use of its resources in pursuit of mission needs and goals. Correlation analysis was used to identify key factors associated with MC rates and applied multiple linear regression analysis to help explain and forecast aircraft MC rates. Specifically, quarterly MC rates for Air Force F-16C/D aircraft, from FY93 to FY00 were analyzed. The F-16C/D was selected so an in-depth analysis could be conducted on a single aircraft type, as opposed to a superficial analysis of multiple aircraft types.

Factors Associated with TNMCM

The TNMCM rate describes the percentage of aircraft NMC due to one or more maintenance conditions. A grounding maintenance condition could be almost anything, ranging from the replacement of a leaking fuel cell to the completion of scheduled maintenance or a time compliance technical order (TCTO). As most aircraft maintenance personnel already know, the amount of TNMCM time an aircraft accumulates is related to and influenced by many different factors—some easily measured and some not. A study conducted by the Dynamics Research Corporation (DRC) for the Air Force Directorate of Supply identified factors—such as manning, experience, retention, increased inspections, modifications to aging aircraft, break rates, cannibalizations, increased man-hours, OPSTEMPO, and aircraft maintenance management policy changes—as being directly related to changes in the amount of TNMCM hours.[8] Factors identified in DRC's study, along with preliminary analysis from the Air Force Logistics Management Agency's (AFLMA) TNMCM study, suggest that these and other factors can, by and large, be grouped into two categories, personnel and R&M.

Personnel. Personnel are key to the readiness equation. Many factors must be considered when addressing the relationship between personnel and TNMCM rates. Studies have indicated that changes in the maintenance area in manning levels, experience, morale, and retention are related to changes in TNMCM rates. While some of these factors are easily quantified (manning levels and number of noncommissioned officers [NCO]), others are not (experience and morale). With respect to the quantifiable factors, several studies have indicated that manning levels in the enlisted maintenance career fields (2AXXX and 2WXXX) appear to be negatively correlated to TNMCM hours.[9] As the number of people in these career fields decreased, the number of TNMCM hours increased.[10]

Not only does the number of people relate to TNMCM rates, the experience of personnel (defined as skill-level or years of service [YOS]) does as well. DRC's study found that reductions in the number of five- and seven-level technicians, as well as a reduction in the number of NCOs, were negatively correlated with TNMCM hours.[11] Furthermore, preliminary analysis from AFLMA's *Cost and Valuation of Air Force Aircraft Maintenance Personnel* study revealed the same relationship in terms of YOS.

Personnel	Environment	Reliability & Maintainability	Funding	Aircraft Operations	Logistics Operations
Personnel assigned or authorized	OPSTEMPO factors	TNMCM hours	Replenishment spares funding	Aircraft utilization rates	TNMCS hours
Personnel in each skill-level (1, 3, 5, 7, 9 and 0)	PERSTEMPO factors	Maintenance downtime/reliability	Repair funding	Possessed hours	Base repair cycle time
Personnel in each grade (E1-E9)	Number of deployments	Mean time between failures/mean time to repair	General support funding	Average sortie duration	Order and ship time
F-16 maintenance personnel in various Air Force specialty codes (AFSC)	Policy changes	Code 3 breaks	Contractor logistics support funding	Flying hours	Level of serviceable inventory
F-16 maintenance personnel by skill-level per AFSC	Contingencies	8-hour fix rate	Mission support funding	Sorties	Level of unserviceable inventory
F-16 maintenance personnel by grade per AFSC	Vanishing Vendors	Reparable item failures	O&M funding	Flying scheduling effectiveness	Supply reliability
Retention rates for F-16 maintenance personnel	Weather	Cannibalization hours/actions	Initial spares funding	Type mission (DACT, CAP, and so forth)	Supply downtime
Personnel per aircraft ratios	Aircraft age	Repair actions/hours	Acquisition logistics funding	Over-Gs	Depot repair cycle time
Maintenance officers assigned or authorized	Aircraft mission (training, test, combat)	Maintenance man-hours		Airframe hours	Maintenance scheduling effectiveness

Table 1. Potential Factors Affecting MC Rates

As the number of trainees (1-4 YOS) for bomber crew chiefs increased, bomber MC and 8-hour fix rates decreased (Figure 2).[12] Obviously, this is not a cause-and-effect relationship. Nonetheless, a mathematical, as well as intuitive, relationship exists.

R&M is another area that dramatically influences TNMCM rates. Both are defined as follows:

> Reliability is the probability an item will perform its intended function under stated conditions for a specified interval or over its useful life.
>
> Maintainability is the ability of an item to be retained (preventive) or restored (corrective/unscheduled) to a specified condition, when maintenance is performed by personnel having specific skill-levels, using prescribed procedures and resources, at each prescribed level of maintenance and repair.[13]

As a system's cumulative operating time increases, the probability of its failure tends to increase, decreasing the system's potential reliability. Reliability also decreases when the conditions under which the system was designed to operate change.[14] The average Air Force aircraft is 20 years old, with 40 percent of the fleet 25 years or older. Many of these aircraft are at critical points in their life cycles.[15] For example, many F-16s have reached 2,400 hours flying time, a significant point in an 8,000-hour service life. As these aircraft age and operating conditions change, the reliability of systems and components decreases, and failures occur more often, which increases maintenance costs. Increased failures affect aircraft maintainability, requiring more maintenance and often increasing repair times when more *hard breaks* occur. In the case of the F-16, operational usage has been more severe than design usage (eight times more), resulting in the acceleration of its airframe service life at a rate that may not let it reach its expected overall service life.[16]

In spite of increased operational usage, fighter aircraft break rates have increased only slightly. However, break rates only account for grounding pilot-reported discrepancies and, therefore, cannot serve as the sole indicator of aircraft reliability. Other maintenance problems discovered during routine and special inspections and while performing maintenance also affect R&M. For example, preliminary analysis from AFLMA's TNMCM study found the number of TNMCM hours attributed to phase maintenance inspections increased 174 percent from 1995 to 1999.[17] In the Air Combat Command (ACC), F-16 fuel

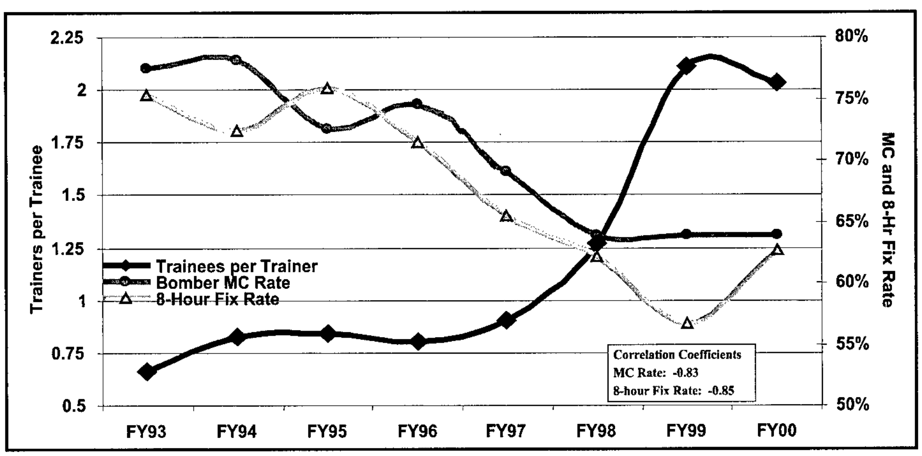

Figure 2. Relationship of Trainees per Trainer to Bomber MC and 8-Hour Fix Rates

leaks, F-15 flight control delamination problems, and cracked A-10 fuselage station 365 bulkheads, none of which are typically pilot-reported discrepancies, are just a few of the TNMCM R&M drivers that have negatively impacted these weapons systems in recent years.[18] Additionally, reduced R&M associated with high failure rates of F-15 and F-16 engine components resulted in substantial increases in the accumulation of TNMCM time.[19]

Declining R&M has also affected TNMCM time in another way. To improve R&M, numerous inspections and modifications have been initiated and implemented, many of which manifest themselves in the form of TCTOs and special inspections. Preliminary analysis obtained from AFLMA's TNMCM study of the F-16 block 42 aircraft revealed the total man-hours expended on TCTOs increased 120 percent from FY95 to FY99 and the man-hours per TCTO event increased 69 percent, indicating TCTOs may be becoming more manpower intensive and technically challenging. The analysis also indicated that low manning and fewer experienced technicians contributed to increases in man-hours required to complete them.[20] While modifications and inspections are necessary to increase overall R&M and maintain the long-term health of an aging fleet of aircraft, they will continue to comprise a substantial portion of reported TNMCM time.

Factors Associated with TNMCS

The TNMCS rate describes the percentage of aircraft NMC due to the unavailability of spare parts. Several factors influence the amount of TNMCS hours an aircraft accumulates. Like the factors that influence TNMCM time, some TNMCS factors can be quantified, while others cannot. Some of the factors currently measured include component reliability and demand, as well as logistics operation factors such as proper mix and level of inventory, component repair times, and order and ship time (O&ST). Other factors, just as important but not easily quantified, are diminishing manufacturing sources, material shortages, and inventory forecasts.[21]

Reliability and Demand. Reliability affects the accumulation of TNMCS time through demand. The more unreliable a component, the more often it fails. Failures necessitate that the component be either repaired or replaced. While either requires initiation of maintenance actions that result in an aircraft accumulating TNMCM time, it also causes TNMCS time to accrue by placing a demand on the supply system. If a part has been designed with sufficient reliability or its reliability characteristics are well understood, the appropriate level of inventory or repair capacity or capability can be established to ensure demands for the part are satisfied in a manner that maximizes aircraft availability and reduces TNMCS time.[22]

In the 1990s, the reliability of many aircraft components declined. One of the main reasons attributed to reduced reliability has been aircraft (and their components) operated outside the set of conditions for which they were designed. This condition primarily manifests itself in the form of aging aircraft and increased failures brought about by the increased OPSTEMPO of weapons systems.[23] For many different reasons, aircraft designed for a certain expected service life and certain operating conditions are being operated beyond those limitations. This resulted in the premature failure of many components that had not been anticipated.[24] In a 1998 article on aging aircraft, Colonel Irving Halter, 1st Fighter Wing Operations Group Commander, stated:

> In 1997, the wing sent 16 F-15s to Saudi Arabia . . . and over the course of 6 months, they accumulated an average of 485 hours each . . . ordinarily, it would take an F-15 more than a year and a half to fly that much . . . we are finding things breaking on the jets that we had not predicted . . . .[25]

Furthermore, since these failures were not anticipated, sufficient quantities of spares and, in some cases, adequate repair capability were not established. Consequently, delays in obtaining or repairing replacement parts occurred while replacements were sought or repair capability established. In some cases, the delay in obtaining replacement parts grew even longer due to the need to establish contractual relationships with the commercial sector to obtain replacement parts or repair capability.[26]

Level and Mix of Serviceable Inventory. Inventories are used to provide organizations with increased flexibility in executing operations. They give organizations a buffer that allows them to cope with the variability that might be encountered in demand, production, price, and transportation. When inventory levels are reduced, problems once hidden by high inventories (poor reliability, inexperienced work force, or excessive repair times) reveal themselves, requiring management to correct them.[27] The impact of inventory reduction programs driven by Department of Defense (DoD) policy decisions depleted stocks of spare parts throughout the Air Force.[28] As inventory levels dropped, reliability and depot repair process problems became more evident. The lower level of serviceable inventory and the problems it revealed contributed to an escalation in TNMCS rates.[29]

Repair Time. The time it takes a depot or contractor to repair and return a reparable item to serviceable condition also affects TNMCS time. Under two-level maintenance, most intermediate base-level repair capability was eliminated. Consequently, the majority of reparable parts are sent to depot or contractor repair facilities where they are either condemned or repaired and returned to serviceable inventory stocks. Two-level maintenance eliminated a significant portion of an operational unit's ability to manage and control its TNMC hours. Repair times vary among components and repair facilities and are influenced by factors such as repair capacity, funding, personnel levels, skill, and policy decisions.[30] One of the major policy issues affecting depot production was the announcement of the closure of two air logistics centers. According to former Secretary of the Air Force F. Whitten Peters:

> Directly relevant to readiness were the closures of two of the five Air Force maintenance depots . . . almost immediately upon announcement, these closures created turmoil at our depots as skilled workers started to leave the closing depots well in advance of the actual closure dates. The most serious aircraft readiness problems . . . were caused by our inability to move depot production lines on schedule and . . . our inability to hire skilled manpower at the receiving depots . . . we are still hundreds of people short at two of our depots.[31]

Further illustrating the impact of repair times, a 1990 Air Force Logistics Command (AFLC) study revealed it took about 30 days to repair an item at a depot.[32] More recently, an F-16 logistics chain management study performed by KPMG found depot repair time averaged 34.9 days for ten critical F-16 avionics components.[33] Additionally, data collected by Synergy, Inc, from the Recoverable Consumption Item Requirements System

(D041) and a General Accounting Office report indicate repair time at the depot is the lengthiest portion of the Air Force reparable pipeline.[34]

O&ST. Another variable that influences TNMCS time is O&ST, which begins when the customer initiates an order with a depot for a replacement part and ends when it is received.[35] O&ST is highly dependent on the availability of serviceable inventory and is significantly affected by shipping and transportation factors. Data collected by Synergy revealed that O&ST, from the third quarter of FY98 to the second quarter of FY99, averaged 7.4 days for 121,516 transactions,[36] while an earlier AFLMA assessment suggested an average O&ST of 16.4 days.[37] However, when a serviceable part is not available, O&ST could encompass the entire repair cycle time (waiting for the failed component to be repaired and shipped back to the unit that sent it), making it possible for large variances. The KPMG study focused on ten critical F-16 components and found that O&ST for these items averaged 37 days, which appears to encompass the component's entire repair cycle.[38]

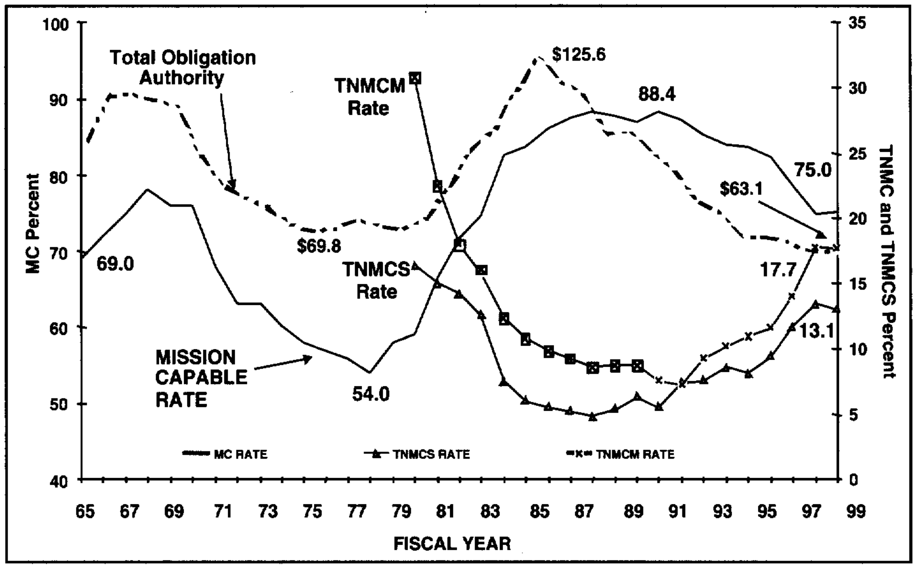

Figure 3. Total Obligation Authority Versus MC Rates, 1965-1999[43]

Underlying Factors Simultaneously Affecting TNMCM and TNMCS

Some factors individually affect TNMCM and TNMCS rates, and some factors, when altered, affect both rates simultaneously. Three underlying factors affecting both TNMCM and TNMCS rates are funding, aircraft operations, and the environment. While none causes readiness, each can significantly affect it. Funding provides the resources used to achieve readiness, while aircraft operations and the environment provide the conditions that shape it. While the nature of some of these factors makes the degree to which they affect readiness difficult to quantify, virtually all the research shows they impact it.

Funding. Funding is one of the common denominators affecting both TNMCM and TNMCS in the MC equation. While funding cannot cause readiness, the amount of funding made available can have a significant impact upon it. If there is no funding available, there probably will be no people or equipment available either since there is a cost for having both. Furthermore, proper allocation of limited funds also needs to be made among competing requirements. Fully funding spares purchases while underfunding personnel could lead to the Air Force having plenty of spare parts but not enough people to install them.[39] A DRC study found that FY95 and FY96 funding for spare parts through the AFMC Materiel Support Division was 58 percent and 74 percent of the requirement. According to the study, this level of funding had a negative impact on MC rates. Furthermore, the study concluded that, if funding for spare parts is even marginally less than the requirement, the result would be less aircraft availability. If inadequate funding exists or funds are not properly allocated, MC rates may suffer.[40]

While many examples illustrating the effect of reduced funding on readiness such as fewer spare parts and manpower reductions are obvious, others are less apparent. For example, reduced funding for R&M enhancements of existing weapons systems, infrastructure maintenance, or training tends to have a more subtle impact on MC rates that is not immediately apparent.[41] Some of the literature highlights lower O&M funding, coupled with increased competition for these limited funds (primarily unplanned contingency operations), as another contributing factor to lower MC rates. When the cost of contingency operations is not fully paid for by budget or supplemental appropriations, the remaining balance may come out of other accounts such as O&M. Even temporarily shifting funds in and out of O&M accounts can have a disruptive and negative impact on training and maintenance.[42] Figure 3 depicts how the Air Force's total obligation authority (TOA) is related to MC rates over time.

Environment. The DoD environment also affects MC rates. The end of the Cold War transformed a fairly stable defense environment to a very dynamic one, causing numerous changes, both internally and externally, in both DoD and the Air Force. The changes affected almost every facet of the Air Force, from its structure and operations to its funding and personnel. For the Air Force, substantial increases in the OPSTEMPO and personnel tempo (PERSTEMPO), the frequency and size of workload on both personnel and equipment, resulted from the new defense environment. Since the early 1990s, the number of deployments and contingency operations has increased tremendously, driving up OPSTEMPO and PERSTEMPO. According to a RAND study, the number of flying hours devoted to Air Force military operations other than war soared from about zero at the end of the Cold War to a point where they consume more than 10 percent of the active duty flying hours, placing unanticipated, heavy demands on support personnel and equipment.[44]

Increases in OPSTEMPO and PERSTEMPO have negatively affected both equipment and personnel, forcing both to work longer and harder. While no sole measurement captures OPSTEMPO or PERSTEMPO in its entirety, the research does outline their effects, many of which have been discussed already and are measurable. Some of the effects are decreased aircraft R&M and spare parts inventories, increased maintenance man-hours and deployments, and reduced retention and morale.[45] The

impact of some of these effects can be seen in changes in monthly F-16 MC rates from 1990-1999 (Figure 4). Coupled with reduced funding levels, the effects of OPSTEMPO and PERSTEMPO can be magnified even more. Furthermore, it is expected that the effects of OPSTEMPO and PERSTEMPO will continue to grow if they are not reduced or at least properly supported.[46]

Figure 3 not only illustrates the effects of funding and R&M but also demonstrates the effect maintenance management decisions can have on MC rates. The management techniques employed in and applied to aircraft maintenance can influence the amount of TNMCM or TNMCS time an aircraft accumulates. At unit level, poor planning and use of resources might result in an aircraft's being NMC for longer periods than necessary. Furthermore, changes to logistics policies initiated by different headquarters can also affect MC rates. While the Air Force does not identify and quantify most of these changes, it is important to note the potential effect these changes might have on MC rates.

One of the biggest changes in aircraft maintenance during the early 1990s was the implementation of two-level maintenance. For many weapons systems, the implementation of two-level maintenance eliminated intermediate-level maintenance (wing-level repair shops) through reductions of people and equipment, transferring that repair capability to the depots. Two-level maintenance achieved its goals of cost savings and reduction of the logistics footprint, saving $259M and eliminating 4,430 positions.[48] However, even with these successes, it affected MC rates by reducing both the repair capability and flexibility of operational units. When an aircraft is grounded because of a failed part and the unit cannot acquire a replacement from the supply system in time for the aircraft to fly its next scheduled mission, the unit typically cannibalizes the replacement part from another aircraft (when it is a *feasible cannibalization*). Cannibalizing parts doubles the time spent on maintenance and increases the probability of damaging the part.[49] While the rate of cannibalization is affected by many factors, meaning that increased cannibalizations cannot be attributed solely to the implementation of two-level maintenance, the overall rate of cannibalization has increased by 78 percent since the inception of two-level maintenance in the early 1990s.[50] Further compounding the problem were the different maintenance priorities being applied by operational wings and depots. The main priority of operational wings was acquiring the proper parts as quickly as possible to return broken aircraft to fully MC status. The depots' primary concern was repairing parts in a cost-effective manner. In many instances, this meant that depots would delay repair activities until enough parts accumulated so it was cost-effective to repair them, forcing wings to either cannibalize parts or accumulate TNMCS hours when serviceable parts inventories were depleted.[51]

Another maintenance management change involved the area of maintenance status reporting. Until FY97, ACC aircraft were returned to MC status after all maintenance was complete but before operational checks had been completed. However, in FY97, ACC changed its policy, requiring aircraft to be returned to MC status after all maintenance and operational checks were complete. This change led to an increase in the number of TNMCM hours accumulated. According to a TNMCM study conducted at Hill AFB in 1997, operational checks accounted for approximately 5 percent of the total TNMCM time.[52] While this represents only a small amount of total TNMCM time, it has been identified as one of the factors responsible for its recent increase.

In the early 1990s, the Air Force initiated an organizational change in most major commands that drastically altered maintenance and may have influenced TNMCM and TNMCS rates: implementation of the objective wing structure. The objective wing structure removed the day-to-day leadership and oversight of flight-line maintenance operations provided by each wing's senior maintenance officers and staff and transferred that responsibility to the less maintenance-savvy operations community, leaving the structure of the maintenance complex fragmented. While the senior leadership in the operations community was perfectly capable, the increased scope of their responsibilities—flying operations and flight-line maintenance—as well as lack of in-depth maintenance experience, may have led to less than optimal decisions concerning aircraft maintenance.[53] This lack of in-depth maintenance management knowledge and experience within the new structure was validated by the creation of the Deputy Operations Group Commander for Maintenance position.[54]

Forecasting and Regression

Forecasting MC Rates. General Ryan's question and the recent concern over decreased readiness were the primary reasons regression analysis was selected over time-series forecasting techniques as the methodology used for the study. Regression models not only provide a forecast but also explain the functional relationship between the dependent variable (MC rates) and numerous independent factors (personnel, component failures,

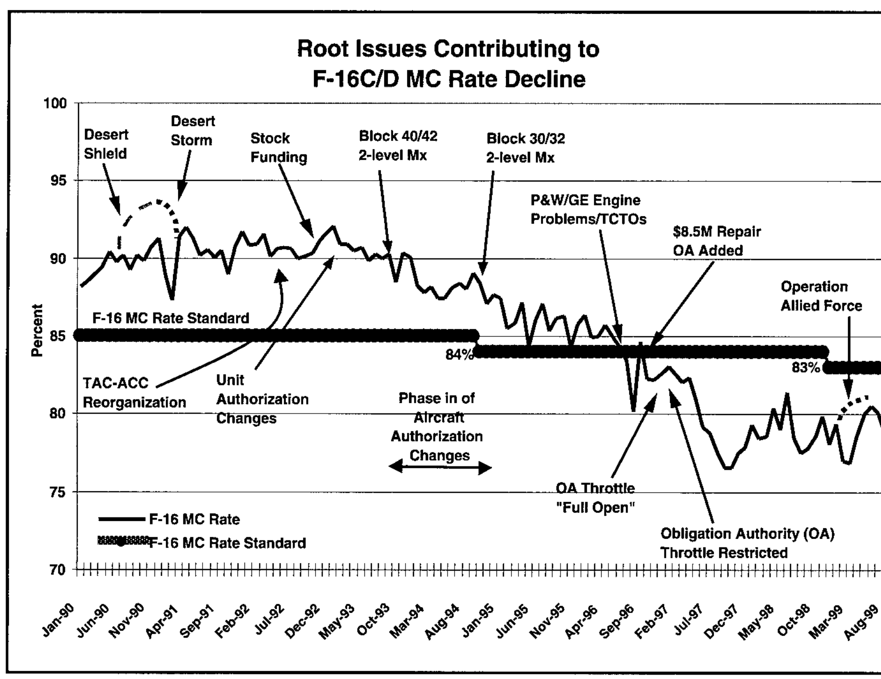

Figure 4. F-16C/D MC Rates, 1990-1999[47]

and so forth). Using regression analysis to explain and forecast MC rates in this study provides two critical pieces of information—first, a forecast that allows for planning and, second, potential causes for the forecast that might be manipulated to alter the projected forecast.[55]

FAMMAS Model. The Air Force has a multitude of tools for forecasting MC rates. It has more than 30 models that can forecast MC rates; however, most are aircraft-specific and, therefore, cannot be used with different aircraft.[56] FAMMAS is the Air Force's primary forecasting tool. FAMMAS output data are primarily used in performing POM and budget assessments and weapons system assessments and are used in the sustainment executive management reporting process. Presently, DRC operates the model, validating the current version of the model (3.0.1) in September 1996. It is a time-series model that uses past, present, and future annual spares funding profiles to forecast MC rates for different weapon systems. It also uses elements such as inflation, carryover, and lead-time factors, as well as historical TNMCS and TNMCM rates (used as adjusting factors) when computing forecasts. Data come from the unit cost document, Reliability and Maintainability Information System (REMIS), and other reliable sources are used in a time-series forecasting algorithm to produce an MC rate forecast.[57]

FAMMAS has proven to be a fairly accurate forecasting model. According to the Defense Science Board Task force on Readiness, FAMMAS, in conjunction with other Air Force systems, has predicted peacetime MC rates for each aircraft in the inventory with an accuracy of +/- 2 percent over 3 years and +/- 5 percent forecasting over 6 years.[58]

Data, Sources, and Factors

REMIS. REMIS contains numerous factors (R&M and others) that relate to MC rates in varying degrees. For this analysis, status, utilization, and on/off equipment maintenance and repair data for each F-16C/D work unit code (WUC)—a five-digit alphanumeric code that identifies individual aircraft systems, components, and processes—were extracted from REMIS. This resulted in each REMIS factor (repair actions, TNMCM hours, and man-hours) having its data broken down to the five-digit WUC level, allowing links to be established between each factor and specific datasets of WUCs for specific F-16C/D systems, components, or processes.

Many REMIS factors were enhanced so a more in-depth analysis could be performed. It was believed the enhanced factors would provide greater insight into how REMIS factors for specific WUCs impact MC rates. To create these enhanced factors, a rank-ordered list of WUCs was developed for the entire 8-year period for each factor (man-hours, TNMCM hours, supply reliability, TNMCS hours, and repair hours) based on the total number of hours accumulated by each WUC each quarter. From those rank-ordered WUC lists, data pertaining to the top 50 WUCs were used to determine how each factor's top 50 ranked WUC dataset (the 50 most significant WUCs) was related to MC rates. Analyzing the REMIS data in this manner focused the analysis on specific groups of WUCs, each factor, and its relationships to MC rates.

Recoverable Consumption Item Requirements System. To determine how logistics operations factors influence F-16 MC rates, data from FY92-FY00 pertaining to these factors were retrieved from the D041 (since replaced by D200). The D041 system is a wholesale-level supply management system used to compute reparable and consumable spare parts requirements by national stock number (NSN) for all customers, worldwide, on an aggregate basis. The system collects a wide variety of quarterly data from different systems pertaining to reparable items such as failures, lead times, base and depot repair times, and excess inventory.[60]

Personnel Data System (PDS). Personnel issues were repeatedly cited as major influences on MC rates. To assess the influence of these factors on F-16 MC rates, personnel data were obtained from the Air Force Personnel Center (AFPC) data system. Data for enlisted personnel with control AFSCs assigning them to the manned aerospace maintenance (45XXX and 2AXXX) and the munitions and weapons (46XXX and 2WXXX) career fields were retrieved as well as personnel data for officers assigned to the 21AX and 405X career areas. In an effort to include only those personnel associated with F-16 maintenance in the research, Air Force Instruction 36-2108, *Airman Classification*, was reviewed and ACC career-field functional managers were consulted to identify the AFSCs that would typically be assigned to provide F-16 maintenance support. All other AFSCs not associated with supporting F-16s were excluded from the data. While some of the AFSCs included in the study typically support only F-16 aircraft (crew chiefs and avionics AFSCs), other AFSCs (fuels and structures) support not only the F-16C/D but also a wide variety of aircraft. Both types of AFSCs were included in this research.

Methodology, Analysis, and Results

Correlation Analysis. Factors from only four of the six areas (personnel, R&M, aircraft operations, and logistics operations) were analyzed. Factors from the remaining two areas (environment and funding) were not analyzed because of the difficulties and complexities associated with obtaining and quantifying factors in these categories. Because of the large number of factors obtained and created for the analysis, a correlation analysis was performed to examine the strength of the relationship between each independent factor and the dependent variable (MC rate) to determine which factors should be included in the explanatory and forecasting regression models. Additionally, each factor was lagged against MC rates with respect to time (one to four quarters into the future) to analyze the relationship between a factor in one quarter and the dependent variable (MC rate) in future quarters. For example, the number of five-levels in the first quarter of a particular year may be more strongly associated with the MC rate that occurs two quarters into the future (the third quarter) rather than the MC rate of the first quarter.

The factors demonstrating strong correlation with MC rates were also classified as to whether each could be controlled with respect to the future. Classifying the factors in this manner identified all the controllable factors to be considered for inclusion in the forecasting model. For example, several processes (recruiting, funding, cross-training, and drawdowns) are used to ensure a specific number of F-16 crew chiefs are in the Air Force at some future point in time. Furthermore, each of those processes can be manipulated to alter the specific number of F-16 crew chiefs to adjust for projected changes in future requirements. However, in the case of the F-16 cannibalization factor, there are no known specific processes or combination of processes that can be manipulated to cause a specific number of

F-16 cannibalizations to occur 2 years into the future. While there may be processes that affect the number of cannibalizations (policies, component reliability improvements, and so forth) that take place, too many unknown factors will still influence the specific number of cannibalizations, making the final outcome 2 years into the future an uncertainty. The uncontrollable nature of this type of factor allows it to be used only in the explanatory model. The application of these and other criteria ensured both models contained only those factors demonstrating the strongest relationships with MC rates.

A correlation analysis was performed on 606 factors to examine the strength of the relationship between each factor and the dependent variable (MC rate) to determine which should be included in the models. However, when lagged by time (one to four quarters), the number of factors increased from 606 to 3,030. Based on the criterion used in the study, the correlation analysis revealed 1,246 variables that demonstrated either positive or negative relationships with MC rates.

A second correlation analysis was performed, and diagnostic scatter plots (as needed) were developed for these 1,246 variables to help identify cases of multicollinearity (redundancy). The analysis revealed numerous instances of multicollinearity among the maintenance, personnel, and retention factors. For example, the number of three-levels assigned to each of the AFSCs examined was highly correlated with the total number of three-levels assigned in all F-16 maintenance AFSCs. In these instances, the factor thought to best explain these relationships with MC rates was used, significantly reducing the amount of multicollinearity among the factors. For the example cited above, the number of three-levels assigned to all F-16 maintenance AFSCs was the factor used to represent the number of three levels assigned to each specific AFSC. This process reduced the number of variables from 1,246 to 87. Next, simple linear regressions and a third correlation analysis were performed on the remaining 87 factors, and by applying the study's criteria, the number of factors was reduced from 87 to 16. Figure 5 lists the independent factors used in the initial model and contains the full explanatory model.

$$Y = \beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \beta_5X_5 + \beta_6X_6 + \beta_7X_7 + \beta_8X_8 + \beta_9X_9 + \beta_{10}X_{10} + \beta_{11}X_{11} + \beta_{12}X_{12} + \beta_{13}(X_{10}/\{X_{11}+X_{12}\}) + \beta_{14}X_{10}/X_{12} + \beta_{15}X_9/X_5X_{15} + \beta_{16}X_3/X_8 + \epsilon$$

Prediction:	**Y = Predicted F-16C/D Mission Capable Rate**
Original Effects: (Factors)	**X_1 = TNMCM Hours of Top 50 Ranked WUCs**
	X_2 = Cannibalization Hours of Top 50 Ranked WUC
	X_3 = Total F-16 Maint Personnel Assgnd (Lagged 3 Qtrs)
	X_4 = Maint Reliability of Top 50 Ranked WUCs
	X_5 = Average Aircraft Inventory
	X_6 = 8-Hour Fix Rate (ACC)
	X_7 = Total F-16 Crew Chiefs Assigned
	X_8 = Total,O-3, Maint Officers Assgnd (Lagged 3 Qtrs)
	X_9 = Total F-16 Maint Personnel Assigned
	X_{10} = Total 3-Levels Assigned
	X_{11} = Total 5-Levels Assigned
	X_{12} = Total 7-Levels Assigned
Interactions: (Factors)	**$X_{10}/(X_{11}+X_{12})$ = 3-Levels per 5- and 7-Levels**
	X_{10}/X_{12} = 3-Levels per 7-Level
	X_9/X_5 = F-16 Maint Personnel per Aircraft
	X_3/X_8 = Total F-16 Maint Personnel Assigned per Total, O-3, Maintenance Officer (4024/21A3)
Higher Order: (Factors)	**No significant higher order terms were revealed.**

Figure 5. Full Explanatory Model

$$Y = \beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \beta_5X_5 + \beta_6X_6 + \beta_7X_{10}/X_{12} + \epsilon$$

Forecast:	**Y = Predicted F-16C/D Mission Capable Rate**
Original Effects: (Factors)	**X_1 = TNMCM Hours of Top 50 Ranked WUCs**
	X_2 = Cannibalization Hrs of Top 50 Ranked WUCs
	X_3 = Average Aircraft Inventory
	X_4 = Total F-16 Maint Personnel Assigned
	X_5 = Total 3-Levels Assigned
	X_6 = Total 7-Levels Assigned
Interactions: (Factors)	**X_{10}/X_{12} = 3-Levels per 7-Level**
Higher Order: (Factors)	**No significant higher order terms were revealed.**

The original X variables were renumbered to simplify the final explanatory model.

Figure 6. Final Explanatory Model

Backward Stepwise Regression Analysis and the Explanatory Model. The explanatory model was developed to identify and describe the factors that demonstrate potential cause-and-effect relationships with MC rates. The specific multiple regression technique used to develop the explanatory model was backward stepwise regression in which all significant factors are included in the initial regression model. As the model is analyzed, factors that contribute minimally to the predictive or descriptive nature of the model are removed. The reduced model is then rerun and tested to verify the reduced model is statistically equivalent to the initial regression model. If the reduced model is found to be statistically equivalent, the contribution of each factor is reassessed in the reduced model, and once again, the factors found to minimally contribute are removed from the model. As long as each reduced model continued to be statistically equivalent to the initial model, the process of reassessing and removing factors is repeated until only the most significant explanatory factors remain in the model. The end result is a simpler explanatory

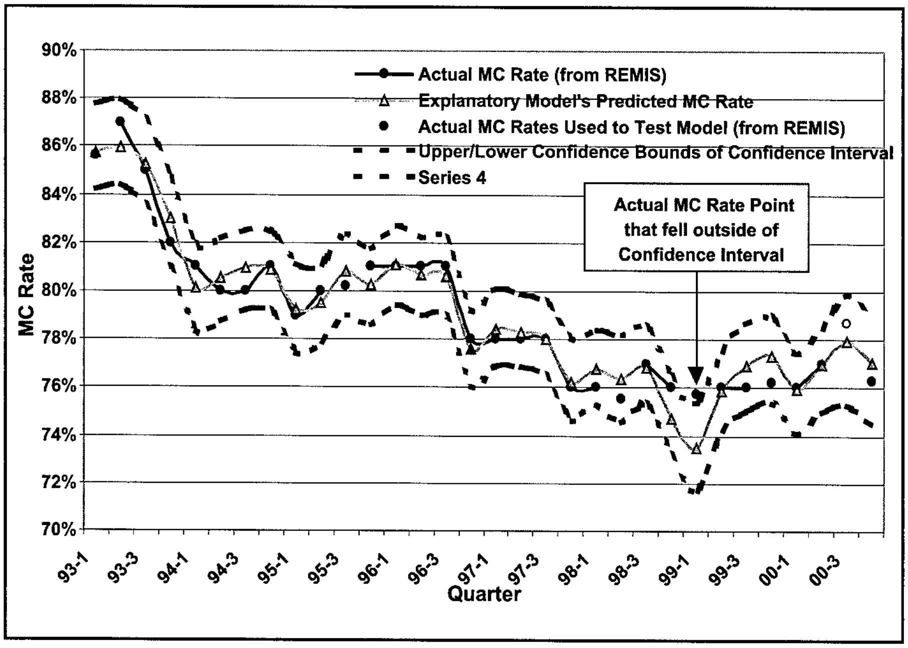

Figure 7. Explanatory Model Sensitivity Analysis

model that is statistically equivalent to the initial model and contains only the most significant independent factors that relate to the independent variable (MC rate).[61]

From the 32 quarters of data plotted over time, 20 percent (seven quarters) were randomly selected and removed from the dataset for model validation and sensitivity analysis. The remaining 80 percent of the dataset (25 quarters) were entered into the JMP_{IN} statistical analysis software package (academic version 4.0.2) to create the full explanatory model. After analyzing and reducing the full model several times, a final explanatory model (Figure 6) with an R^2 of 0.955 can be used to explain or predict F-16C/D MC rates at a 95 percent confidence level.

Sensitivity Analysis of the Explanatory Model. To test the predictive reliability of the final explanatory model, the data that were withheld (20 percent) from the original dataset were combined with the data used to build the model (80 percent). The dependent variables (MC rates) for each of the withheld quarters were excluded from this process so that, when the model was run, the software generated predicted MC rates and confidence intervals (alpha = 0.05). The resulting predicted MC rates were analyzed to determine if they fell within the bounds of the confidence intervals generated by the model. For sensitivity analysis, the total number of predicted observations (predicted MC rates) that fell within the bounds of the confidence interval was divided by the total number of observations (actual MC rates) so the predictive reliability and overall robustness of the model could be determined.

The explanatory model's predictive reliability was computed and revealed the observed MC rates for each respective quarter fell within the individual confidence intervals generated by the model six out of seven times, indicating the model's predictive reliability to be 86 percent. To compute the model's average prediction error, the widths of the confidence interval associated with each predicted MC rate at the prediction points were summed and averaged. The computation revealed the model's average prediction error as being 1.9 percent. The results of the sensitivity analysis for the model are shown graphically in Figure 7.

Multiple Linear Regression and the Forecasting Model. After the explanatory model was developed, a separate multiple linear-regression model was developed to forecast F-16 MC rates seven quarters into the future. The factors to be used to build the forecasting model were those identified as factors that could be controlled directly or indirectly with respect to the future. Consequently, many of these factors were different from those used to build the explanatory model. A series of forecasting models was built using data from the first 80 percent of the time-ordered quarters (FY93-1-FY98-4). Data from the remaining time-ordered quarters (FY99-1-FY00-4) were set aside to assess the model's predictive reliability. To determine which combination of variables produced the most accurate forecast, the mean absolute percentage error (MAPE) was computed for each forecasting model's combination of factors (more than 50 different combinations were tried). The MAPE measures the percentage error (point estimate error) of a model's ability to forecast and is computed by taking the sum of the absolute percent error for each period (absolute difference between the forecast and actual MC rate) and dividing it by the total number of forecast periods.[62]

As a starting point, the model generating the smallest MAPE was the one selected to forecast F-16 MC rates. After building more than 50 models, using different combinations of variables and analyzing the MAPE of each, the following model (Figure 8) generated a MAPE of 0.824 percent, which was the lowest of all the models tested.

Forecasting Model Sensitivity Analysis. Next, the predictive reliability, which could also be described as the usefulness of the model's forecast outputs for planning the forecasting model, was analyzed. The width of the confidence interval served as the indicator of the model's robustness. The narrower the interval,

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_4/X_3 + \epsilon$$

Forecast: Y = Predicted F-16C/D Mission Capable Rate

Original Effects: (Factors)
X_1 = Sorties
X_2 = Flying Hours
X_3 = Average Aircraft Inventory
X_4 = Total F-16 Maint Personnel Assigned

Interactions: (Factors) X_4/X_3 = Total F-16 Maint Personnel per Acft

Higher Order: (Factors) No significant higher order terms were revealed.

Figure 8. Forecasting Model—Version 1

the more robust the model; alternatively, as the interval widens, the model's robustness decreases. The initial model's (version 1) average prediction error was computed (average width of the confidence interval for the forecast period that the actual MC rate should fall within), along with a series of alternative models, to determine its robustness; the smaller the average prediction error, the more robust the model.

The actual MC rates were plotted over time along with the predicted MC rates and the associated confidence intervals (alpha = 0.05) generated by running the model (Figure 9). First, the average prediction error for the forecast period was analyzed in the same manner as the explanatory model and was found to have an average prediction error of 4.8 percent and an R^2 of 0.779. Next, the average prediction error of the forecasting model (version 1) was compared to the other 50 models to validate its robustness. The comparison revealed one of the alternative models (version 2, Figure 10) produced a narrower confidence interval and prediction error of 2.1 percent and narrower confidence interval than that of the initial forecasting model (version 1). Even though forecasting model version 2 generated a higher MAPE (1.25 percent and an R^2 of 0.943) than that of version 1, the criterion used to assess the robustness of the model (narrower confidence interval) makes version 2 a more robust alternative for use in long-range planning (Figure 11).

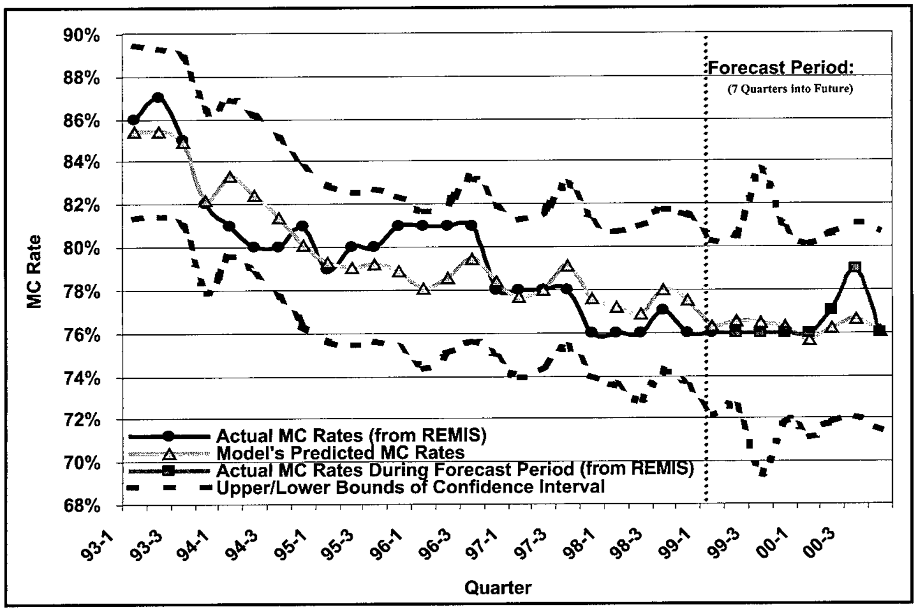

Figure 9. Forecasting Model (version 1) Sensitivity Analysis

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_4/X_3 + \epsilon$$

Forecast: Y = Predicted F-16C/D Mission Capable Rate

Original Effects: (Factors)
X_1 = Sorties
X_2 = Average Aircraft Inventory
X_3 = Total 5- and 7-levels Assigned (Lagged 4 Qtrs)
X_4 = Total, O-3 Maint Officer Assigned (4024/21A3) (Lagged 3 Qtrs)
X_5 = Total 9-levels Assigned
X_6 = Percentage of 2d Term Eligibles Reenlisting

Interactions: (Factors) No significant interactions were revealed.

Higher Order: (Factors) No significant higher order terms were revealed.

Figure 10. Forecasting Model—Version 2

Conclusions

One of the questions research for this article tried to answer was, "Which factors are related to MC rates and what are the associated relationships?" From the analysis, it was quite apparent that some categories of factors were more strongly related to MC rates than others. R&M factors demonstrated the strongest relationships; however, this was not unexpected since many of these factors are used to compute MC rates. The most meaningful factors from this area were the R&M factors ranked over time. These factors were designed to link the number of hours or occurrences a specific group of F-16C/D WUCs ranked over time to F-16C/D MC rates. Analyzing the data in this manner transformed it and made it more meaningful. Instead of analyzing how accumulated hours of quarterly maintenance or supply time relate to MC rates, the ranked variables demonstrated how the cumulative quarterly maintenance hours of the 50 most problematic WUCs over the last 32 quarters related to MC rates. Although the ranked measures were more meaningful than the summed quarterly WUC data, it is important to note that both types of factors do not identify the root causes as to why the WUCs accumulated time against them. However, the factors broken down by WUC highlight those WUCs that appear to have been the most significant over time, allowing maintenance managers to perform root cause analysis and take corrective actions as needed.

When compared with factors from the other two areas, aircraft and logistics operations demonstrated the weakest relationships with MC rates. However, when these factors were linked with either personnel or R&M factors, the new factors demonstrated strong correlation with MC rates. For example, the *total maintainers assigned* factors (by grade, skill-level, and AFSC) were combined with the *average aircraft inventory* factor to create a series of *maintainers assigned per aircraft* interaction factors, linking the category of personnel to aircraft operations. This demonstrated stronger correlation with MC rates than either the *total maintainers assigned* or the *average aircraft inventory* factors by themselves. Consequently, aircraft and logistics operations factors were used primarily to create new variables linking system performance to either R&M or personnel.

The results of the analysis were very similar to the findings of other studies that analyzed how personnel levels relate to MC rates. The underlying factor in the personnel data appeared to be

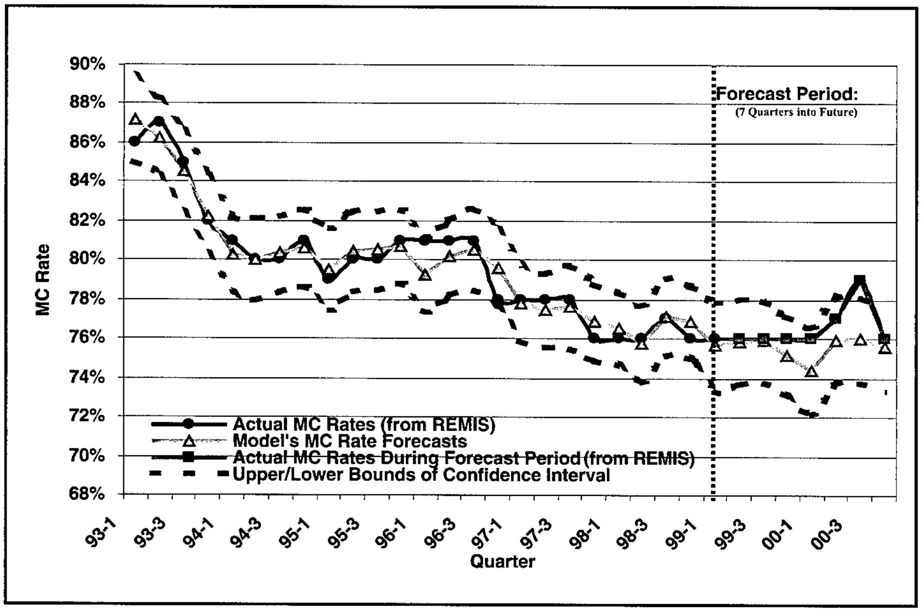

Figure 11. Forecasting Model (version 2) Sensitivity Analysis

experience. Whether the data were analyzed by grade, skill-level, or percent of authorizations filled, the story was the same: as the number of inexperienced people (defined as three-levels and E-1 through E-3) increased, MC rates decreased. Conversely, as experience increased (five-, seven-, and nine-levels as well as E-4 through E-9), MC rates increased. To better understand these relationships in an operational environment, the ratio of three-levels to other skill-levels was thought to be a useful measure of personnel conditions (experience mix) that might exist in a typical maintenance complex. The ratios were created to model the level of responsibility that more experienced personnel are shouldered with when training and supervising new or inexperienced personnel, while simultaneously performing their normal duties. When analyzed, increases in the ratio of three-levels to either five- or seven-levels (or both combined) were negatively correlated to MC rates. A detailed analysis of these ratios for specific AFSCs was less clear. Some AFSCs, such as crew chiefs and flight-line avionics, exhibited the same trends as the top-level analysis of the ratios; however, skill-level ratios for other AFSCs, such as engines and structures, demonstrated positive correlation with MC rates. This could indicate that MC rates are more sensitive to skill-level imbalances in certain career fields than others or that AFSCs typically associated with on-equipment maintenance affect MC rates more than those typically associated with off-equipment maintenance.

Retention and separation variables were also analyzed as part of the personnel data. The data were broken down by AFSC and grade and then by category of enlistment as first-, second-, and career-term airmen to assess how retention rates for these groups of airmen related to MC rates. Instead of analyzing the raw numbers, the data were converted to percent of reenlistment-eligible personnel who reenlist or separate. These factors exhibited varying degrees of correlation with MC rates. The strongest correlation with MC rates was demonstrated by the F-16 crew chief retention rate. Most of the other AFSC-specific retention correlations were very weak. However, overall, first-term, career, and total reenlistment rate correlations were strong. These three retention factors, along with F-16 crew chief retention rates, were the retention variables that appeared to be the most significant in this area of personnel data. The second-term, retention-rate variable, although not found to be strongly related to MC rates, was retained in the regression analysis since several sources cited lower second-term retention rates as having a negative effect on MC rates. This appeared to be the case, as the second-term retention rate factor ended up being included as a variable in the alternative forecasting model (version 2).

Other questions this research attempted to answer were, "Which model best forecasts MC rates, and how helpful are these models in demonstrating relationships between the factors and MC rates, and what are the results?" The answer to these questions is a resounding, "It depends." Many good regression and time-series models can be developed, and some models are more useful than others. However, unlike most time-series models, regression models can be used to describe relationships among factors as they relate to the independent variable (MC) and provide forecasts. Furthermore, there are many different criteria that can be used to select the best model. The real answer as to which model explains or predicts best resides with the individual or organization using the model and the context in which the model is to be used.

The focus of the explanatory regression model is on explaining how a set of significant independent variables relates to MC rates. The study's explanatory model contained seven different factors, both controllable and uncontrollable, that mathematically explain 95 percent of the *what* behind MC rates. Regarding the explanatory model's uncontrollable factors, further analysis could be performed to discover the root causes behind why a particular factor is affecting MC rates in the manner it is. If the root causes can be identified and prove to be controllable, then the factor could be included in the forecasting model to see how changes in that variable might affect future MC rates.

Different user needs typically require the application of different criteria when selecting the best forecasting model. In this study, if the user's focus is on forecasting a point estimate (that is, the MC rate will be 82 percent 4 quarters from now), the user should use the forecasting model that generates the smallest MAPE (version 1). However, if the user is interested in reducing the prediction error of the forecast (that is, the actual MC rate will fall within +/-2.1 percent of the predicted MC rate), then the user should select the forecasting model that generates the smallest average prediction error (version 2). Once again, the best model is the one that is most useful to the user.

Unlike the explanatory model, the purpose of the forecasting models is to predict what future F-16 MC rates might be seven quarters into the future, given a certain set of future conditions. The forecasting models allow the user to conduct *what if* scenarios to see how changes in the models' variables (controllable variables such as the number of five-levels, sorties,

and so forth) might impact future MC rates. The initial forecasting model, version 1, provides superb point estimates of future MC rates. On average, the model's forecasted MC rate falls within +/- 0.82 percent (MAPE) of the actual MC rate that occurred in the forecast period. Additionally, using this model, there is a 95-percent confidence that the actual MC rate will fall within +/ -4.8 percent of the forecasted MC rate (within the bounds of the confidence interval), making the future planning window rather large.

The alternative forecasting model, version 2, is an excellent long-range planning model because of its small prediction error. With this model, there is a 95-percent confidence level that the actual MC rate will fall within +/-2.1 percent of the forecasted MC rate, which is a significantly smaller future planning window than the window generated by version 1. However, unlike version 1, the forecasted MC rate generated by version 2 normally falls within +/-1.25 percent of the actual MC rate (MAPE), making its point-estimate predictions less accurate, which is why this model wasn't initially selected as the best model.

The study illustrates what most logisticians already know—MC rates are determined by a variety of logistics-type factors (logistics operations, R&M, and personnel), as well as operations-type factors (aircraft operations, funding, and environment) and their interaction. Another conclusion regarding MC rates, although not a primary focus of this study, was reached. In addition to measuring readiness and aircraft availability, the MC rate indirectly assesses how a weapon system was operated and how its logistics support structure performed. A weapon system's operating conditions and its logistics support structure help determine the availability and readiness of that weapon system. To determine how a weapon system might be affected by changes in these areas, its specific logistics and operations factors, as identified above, should be isolated, then simultaneously analyzed. The key is simultaneous analysis. Because each of the factors affect the MC rate in different ways at the same time, they need to be reviewed together (a holistic approach) to understand how they affect the MC rate. As a result, the most significant factors (like experience, cannibalizations, and funding levels) could be identified, monitored, and improved as needed. Simultaneous assessment should determine a more comprehensive set of key indicators which could provide a better picture of how significant logistics and operations factors affect the way the logistics support structure sustains a weapons system and shapes its future availability—its readiness—its MC rate.

Notes

1. Robert H. Williams, "Readiness Pledge by Pentagon Prompts Challenge from Congressional Leader," *National Defense*, Jul-Aug 97, 82, 24-25.
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("MICAP Shipping Policies" continued from page 5)

In another real-world example from the recent past, the vehicle operations flight at McGuire AFB, New Jersey, would pick up and deliver MICAP items to and from Dover AFB, Delaware, and NAS Norfolk, Virginia, almost daily. However, in the data, there were two shipments from Dover to McGuire AFB via FedEx. There were also five shipments from Norfolk to McGuire AFB via FedEx. These shipments could have been picked up and delivered by the vehicle operations flights at the respective bases faster and, most likely, cheaper than using FedEx. Of the 3,451 shipments, 633 (18.34 percent) were 500 miles or less. This implies there may be some mismanagement in MICAP shipments. As stated in AFI 24-201, MICAP shipments are not to go via an air carrier if traveling less than 500 miles. Another area that should be investigated is whether the LTL carrier's time standards currently meet MICAP time standards? Also, can LTL carriers improve their time standards in order to meet MICAP shipping time standards? After looking at these two questions, the Air Force needs to determine if LTL carriers can provide their current time standards with a lower rate through a negotiated contract with the Military Traffic Management Command (MTMC). Another possibility is for MTMC to negotiate a contract with lower time standards and a lower rate for MICAP shipments. However, before these concepts can be examined, it will be necessary to determine how much additional shipping volume MTMC can promise to an LTL carrier with the improved service and lower rates. For example, would Roadway be willing to negotiate a contract with MTMC with the same time standards and current or lower rates if MTMC could promise a certain number of shipments annually? MTMC's negotiating with an LTL carrier, where a certain percentage of DoD shipments are given to the carrier, may result in a greater cost savings for DoD.

Conclusion

Cost savings can be realized using Roadway, as opposed to FedEx, for certain shipments, if cost of the shipment is a major criterion. From this perspective, the Air Force and DoD's current modal and carrier choices are not optimal. Both the Air Force and DoD need to reevaluate the policies directing shipment of MICAP items.

The shipping organization should use the LTL carrier for MICAP items if the carrier's rate is less than FedEx and the LTL carrier can meet the time standards required for delivery. However, to further validate this, additional study that includes more actual MICAP shipping data may be warranted.

Overall, Roadway is a viable alternative, from a cost standpoint, to FedEx for shipping MICAP items within the CONUS and Alaska. Further, additional competition would affect rates. Rates would be reduced if the Air Force and DoD have an alternative carrier for MICAP shipments. FedEx would have to keep its rates down to the level of its competitor. This conclusion is made with the assumption that FedEx and the LTL carrier can maintain the same level of service or the same time standards between pickup and delivery. This also keeps the other express air carriers from raising their rates. The carriers in the air mode would not have an incentive to form a cartel and raise rates if another mode, such as express ground or LTL, were vying for the government's business. If the express air carriers formed a

cartel, they would cut themselves out of the market for DoD express shipping needs.

Most carriers in the LTL marketplace are regionalized, as opposed to the air carriers, which are national. If DoD and the Air Force use LTL, it would increase competition between not only the competing modes but also the LTL carriers. Additionally, DoD possibly would not need to enter a contractual agreement with a national LTL carrier because of the large number of regional LTL carriers. DoD and Air Force use of LTL creates competition for business on a regional and national level. Overall, this competition will result in lower rates.

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("Current Logistics Research" continued from page 23)

It is difficult to determine appropriate stock levels for aircraft components rarely used in peacetime. We demonstrated the significance of various computational assumptions by providing an evaluation of alternative electronic warfare readiness spares package policies.

Based on user feedback, we revised our Cost-Benefit Analysis for the Contract Repair Improvements tool and conducted training for more than 100 people at Air Force depots.

In response to a request from the Aeronautical Systems Center Commander, we partnered with ASC Engineering Directorate and System Program Office (SPO) representatives to identify, evaluate, and recommend models that provide decision makers with a way to analyze investment alternatives in an effort to optimize mission-capable rates. We observed there is a general lack of awareness of the more than 60 models, tools, and methodologies examined. The proliferation of models is caused, in part, by a lack of standardized terminology and parameter definitions. The latest versions of the Logistics Composite Model simulation and Aircraft Sustainability Model were found to be superior for analysis of alternatives involving maintenance, supply, and funding.

The AFMC Logistics Directorate developed readiness spares package budget estimates for the program objective memorandum (POM) more than 10 years ago. However, the major commands recently challenged the factors. Therefore, we developed updates at the weapon system level. The macro-level factors are the percentage of available assets needed to fill the manager's estimates of range and depth-kit growth for each POM year and the ratio of repair cost to purchase price.

In response to a question from the Chief of Staff of the Air Force, we applied the Aircraft Availability Model to determine realistic targets for MICAP hours. Results indicate that it is possible to reduce MICAP hours for aircraft items down to approximately 1.7 million hours per month (a 30 percent reduction) if the real-world behaved like our model.

Our assistance to the SMAG manpower-integrated product team helped design a model that will size work force to workload. We reviewed an Oklahoma ALC Manpower and Organization Division-developed regression model to determine how to modify it for use at all centers.

We evaluated a contractor-developed E-3 simulation model—Forward-Looking Availability and Reliability Simulation—and recommended improvements to the design to accommodate the real-world needs of the E-3 SPO. We updated and extended an existing simulation model for use in the Global Engagement V Wargame. The model estimates the effect of various threats on the capability to generate sorties.

Several internal and external studies used the AFMC logistics response-time analysis system to identify supply chain bottlenecks and measure their severity. Our evaluation of alternatives for improving aircraft engine computations led to a design for an enhanced spares requirements model for engines and components.

Variability in demands greatly complicates inventory management. We investigated the hypothesis that items with high variability tend to cause more readiness problems and found that, indeed, they do. Items with large variations in pipeline quantities generally cause three times as many MICAPs, as compared to items with less variability.

> *In war, the moral is to the physical as three is to one.*
>
> **—Napoleon**

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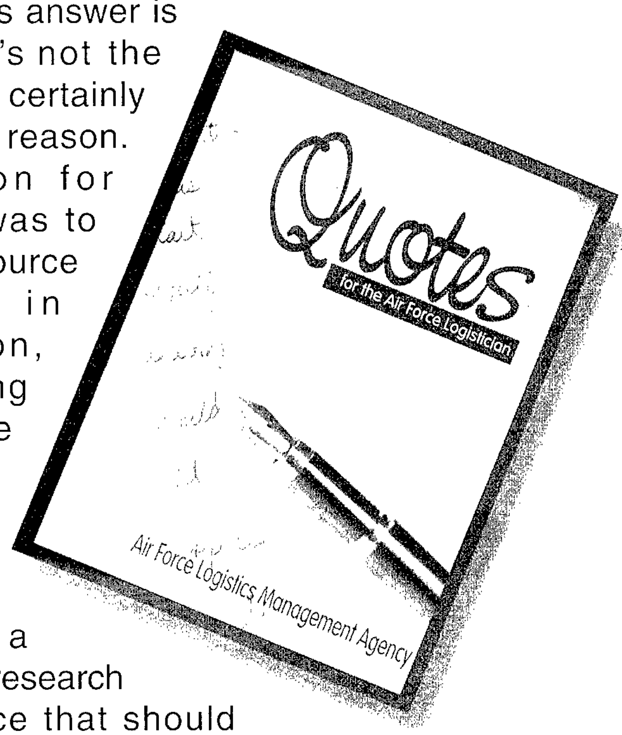

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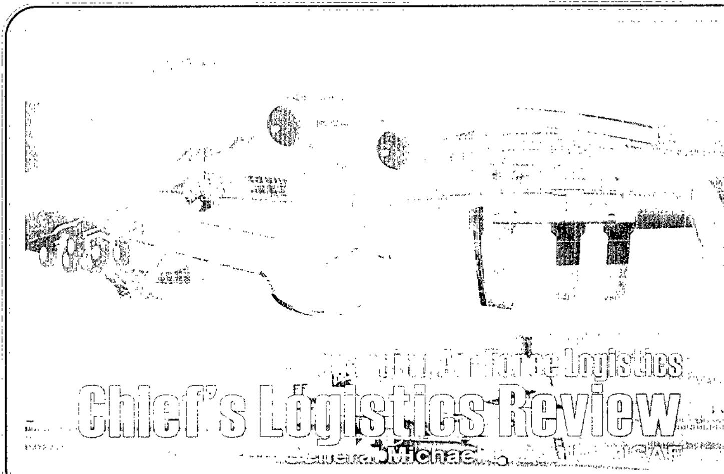

The Editorial Advisory Board selected "Chief's Logistics Review"—written by Lieutenant General Michael E. Zettler, USAF—as the most significant article to appear in the *Air Force Journal of Logistics*, Vol XXV, No 2.